CHART OF JUPITER
for the Opposition of 1888.

By A. S. WILLIAMS.

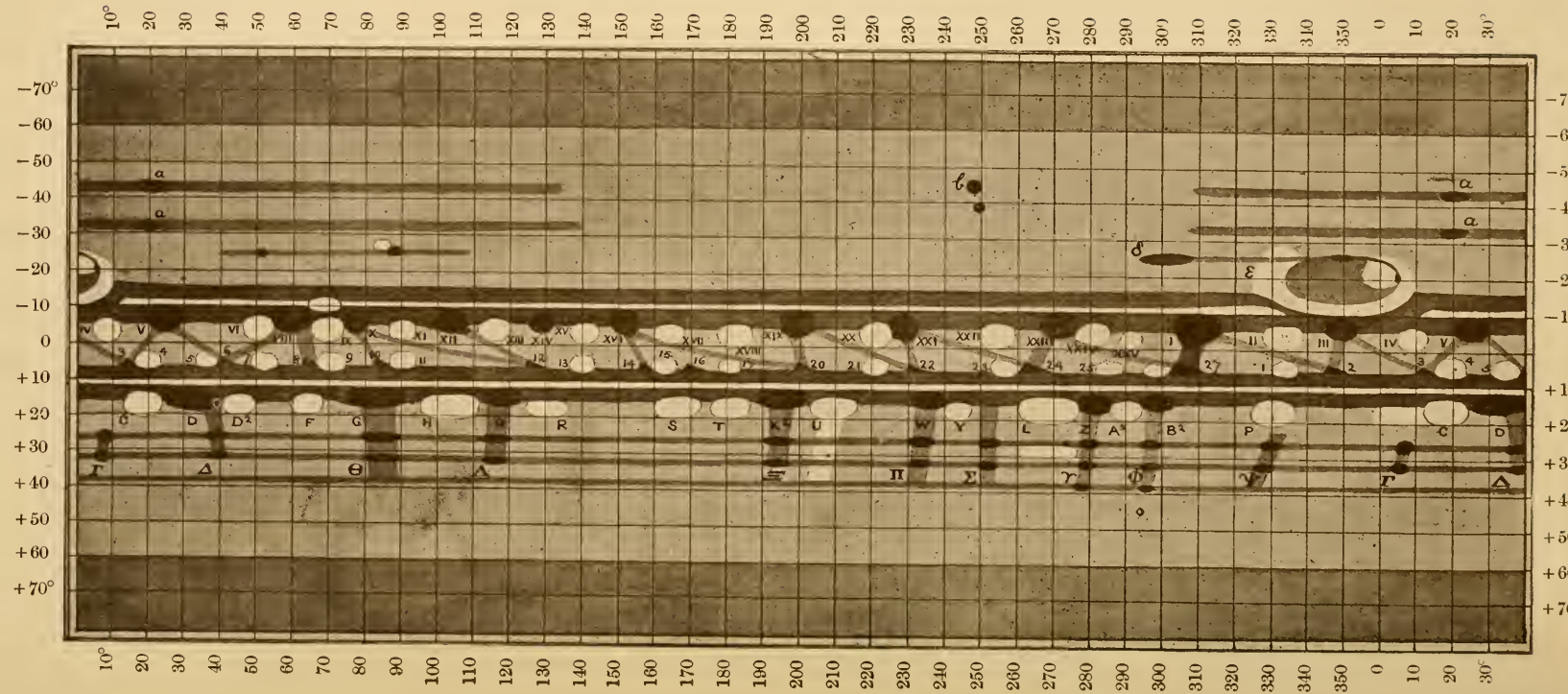

PLATE I.

ZENOGRAPHICAL FRAGMENTS.—II.

20 Hove Park Villas, Hove

With Mr. Williams' Compliments.

An astronomical instrument is not an end in itself, but the means to an end—the making of observations: observations are the stepping-stones to higher ends.

ZENOGRAPHICAL FRAGMENTS.

II.

THE MOTIONS AND CHANGES

OF THE

MARKINGS ON JUPITER

IN 1888.

BY

A. STANLEY WILLIAMS.

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CONTENTS.

PLATES.

INTRODUCTION.

The present volume contains the results of the observations of Jupiter made during the apparition of 1888. As in the previous apparition of 1886–7, the principal feature of the work consisted of numerous transit observations of the spots and other markings, having for their object the determination of the rotation-period, or drift, of the surface material of the planet in different latitudes. By the term "surface material" is meant the material at the *visible surface* of Jupiter, without reference to the question whether such material is actually at the solid, or liquid, surface of the planet, if, indeed, the latter can be said to possess such a thing as a solid or liquid surface. The actual number of observations is considerably greater than was the case in the preceding apparition of 1886–7, chiefly owing to the planet having been kept more systematically under observation. Thus, the total number of observations for longitude is 888, as compared with 329.

In addition to the observations for longitude, a number of measures, chiefly of the belts, were made for latitude with a filar micrometer. Although the belts are not always exactly parallel to the equator, yet they usually are very nearly so, and they seldom depart far from such parallelism. Hence, if the latitudes of the chief belts are measured directly, we can refer the positions of the spots to the belts, in which they are generally more or less involved, and thus also derive the latitudes of the spots, and so the latitudes of the surface currents with a degree of accuracy sufficient for all practical purposes.

Some little time has now elapsed since the publication of Volume I. of these Fragments, containing the results of the observations of the apparition of 1886–7. It is hardly necessary to remark that the effect of further study of the planet, particularly when made under more favourable conditions, has been to modify some of the conclusions of the former volume. This was inevitable, and most of these conclusions were, in fact, actually stated there more or less in an interrogative or tentative manner. It is not necessary to refer to such changes of opinion particularly here, since

the more mature conclusions, and the evidence upon which they are founded, will become apparent in the course of the present and future volumes. In case of any divergence, the later or more recent conclusions should be preferred to the earlier ones.

There is, however, one correction which it does seem desirable to make here. In Volume I., pp. 112 and 113 and elsewhere, the fact that the white equatorial spots were frequently accompanied by a white spot nearly opposite to them in the great rifts of the equatorial belts was considered to show that the equatorial spot and the companion spot in the rift were really one spot apparently divided into two by the overlying dark belt; and as a corollary that the white spots were at a lower level than the dark belts. Subsequent observations, however, made under better conditions, have shown that the equatorial white spots commonly communicate with the bright spots in the rifts by means of real and comparatively narrow channels or canals. The appearances suggest rather that the white material *breaks through* the dark material of the belts, than that it extends under the latter. The probability is that the upper surfaces of both the white spots and the dark belts are actually at nearly the same altitudes. This subject is only just mentioned here, for the evidence upon which this conclusion is based is derived chiefly from the observations of subsequent years, made when the planet was in a much better position for observation than it was in either 1887 or 1888. It is here sufficient to merely state the fact that I no longer consider that the white spots extended under the dark belts.

There is a mingling both of pleasure and regret in publishing a series of observations made many years previously. On the one hand, there is satisfaction in the thought that the work of reduction and discussion has been better and more thoroughly done than would probably otherwise have been the case. On the other hand, there is a mingling of regret, for one feels sometimes that the observing work might have been done better than was actually the case, if only the observer could have set about it in the light of his present knowledge.

Subsequently to the appearance of the first volume of these Fragments there has been published a very extensive series of observations, made in the same year 1887, by Dr. F. Terby at Louvain *. It has always been a matter of regret that I have not been able to make a detailed comparison between our two independent series of observations. Generally speaking, our observations are in excellent agreement, as has been pointed out by Terby

* "Études sur l'Aspect physique de la Planète Jupiter, Troisième Partie," *Mémoires de l'Académie royal des Sciences, des lettres et des beaux-arts de Belgique*, tome li. This memoir contains no less than 84 disc drawings of Jupiter. As it will be necessary more than once to refer to this valuable work, it will be shortly described as Terby's *Third Memoir*.

himself, and the only really important disagreement, if disagreement there be, is one of opinion rather than of observation. Terby at that time, if I correctly understand his meaning, appears to have been rather inclined to question the conclusion that certain details in the neighbourhood of the equator rotated in a period approximately equal to $9^h\ 50^m$, instead of in one of about $9^h\ 55^m\ 40^s$. It seems hardly necessary to formally discuss the question here, since time has conclusively proved that similar details do undoubtedly invariably rotate in approximately the former period, and the observations published in the present volume should in any case suffice to remove any doubt remaining upon the subject. I wish here to call attention to the fact that our two contemporaneous but absolutely independent series of observations afford an excellent opportunity for investigating the interesting though somewhat perplexing subject of the personality of observers in drawing and observing planetary markings.

It is very much to be regretted that hardly any observations of Jupiter seem to have been made anywhere else in 1888. No doubt this was largely due to the very low altitude of the planet in that year, but, apart from this reason, Jupiter appears to have been quite unduly neglected. In Section XIV. I have given references to all the observations of 1888 that are known to me. For the most part they consist of almost isolated observations or sketches. Now, other things being equal, a series of observations is valuable in proportion to its extent. A few desultory observations alone by any one observer are of comparatively little value, for they are insufficient in themselves to enable the nature of the personal peculiarities in observing of the observer to be determined, and hence it is difficult to make any satisfactory comparison with the observations or results of other observers. It has been necessary therefore to rely entirely upon my own observations alone.

There were three features of unusual interest visible in 1888. These were, firstly, a number of little blackish spots which made their appearance on three narrow belts in the northern hemisphere of the planet, accompanied by faint dusky streaks extending in a meridional direction for a long distance towards the north. Next we have two small but definite dark spots in the southern hemisphere, in a latitude unusually far south, where such definite spots are very rare. These two sets of markings have served to determine the rotation-period or drift of the surface material in the higher latitudes of Jupiter. Lastly, we have the remarkable dark spot δ, which must be regarded as foreshadowing the apparition of the great South Temperate Disturbance of 1889–92, which Disturbance resembled in many respects the great South Temperate Disturbance which first made its appearance in 1901 in the same south latitude, and is still visible at the present time, though there were important differences.

A few of the observations included in the present volume have been published elsewhere. Thus, some of the observations of the Red Spot were published in the *Journal of the Liverpool Astronomical Society*, vol. vii. p. 55; and on p. 58 of the same publication will be found the observed transits of the white spot C, on the north side of the North Equatorial belt. The observations of the remarkable dark spot δ, alluded to above, were published in the *Monthly Notices*, vol. lix. p. 30, with reproductions of eight drawings, seven of which also show the Red Spot. Lastly, the observations of the two Southern Spots *a* and *b* were published in the *Astronomische Nachrichten*, Band 139, col. 214.

One thing has been very forcibly impressed upon me in the course of the preparation of the present volume. That is, the great, and in fact almost vital, importance of the publication of *every* observation for longitude of the spots. On no account should any observation be omitted from publication, however discordant or unsatisfactory it may appear to be, or however badly it may seem to fit in with the adopted system of identification. Probably the simplest and generally most satisfactory mode of publication would be in the form of charts, like those forming the last five plates of the present volume, though preferably on a somewhat larger scale. The foregoing remarks will apply with equal force to the planet *Saturn*.

In conclusion, I wish to express my most grateful acknowledgments and thanks for the numerous and valuable publications which have been most kindly and generously sent me by individuals and institutions. Living as I do at a distance from any good Astronomical library, it is in most cases only by means of these precious donations that I have been enabled to become acquainted at first hand with these valuable works. In some cases, I fear, I may have been remiss in returning thanks, but if so it has certainly not been intentional, but due to the fact that the time which I am able to give to astronomical pursuits is strictly limited. I sincerely hope that this will be considered a sufficient excuse for any delay or omission in returning thanks on my part. Also I cannot refrain from an expression of satisfaction and admiration at the many very large and very important series of observations of Jupiter which have been made during the last ten or twelve years, and which reflect the greatest credit upon their respective authors. The amount of work represented by the results included in the tables of Section XIII. is simply enormous, though the real meaning of it can only be properly appreciated by those who have made and discussed, say, 1000 determinations of the longitudes of different markings. Nor must we forget the various series of observations which have been published, but which have not hitherto been reduced or discussed, so that the results are not yet available for purposes of comparison; nor yet

the numerous valuable drawings and descriptions of Jupiter. For accurate delineation and description should go side by side with determinations of longitude and latitude, if we are to make any decided advance in our knowledge of the planet. There is a tendency in some quarters to depreciate the value of mere drawings of the planets, but assuredly this feeling is not shared by the present writer. The value of good planetary drawings cannot easily be over estimated.

It is with great regret, whilst engaged in correcting the final proof, that I hear of the death of Major P. B. Molesworth. Although a successful observer in other departments of Astronomy, it is in connection with the planet Jupiter that his name will be chiefly remembered. A most careful, painstaking and skilful observer, he was endowed also with amazing energy and enthusiasm. As an illustration of this may be mentioned the fact that during a single opposition of Jupiter he observed no less than 6758 transits of spots; and during another opposition as many as 5651 transits, besides making many micrometer measures for latitude and numerous miscellaneous observations. He was also an excellent draughtsman.

ZENOGRAPHICAL FRAGMENTS.

SECTION I.

THE INSTRUMENT AND METHOD OF OBSERVATION.

The telescope with which the observations were made is a silver-on-glass reflector by Calver, having an aperture of 165 mm. and a focal length of 1·944 metres, and equatorially mounted, but without driving-clock. The eyepiece nearly always used was formed of a single plano-convex lens, giving a magnifying-power of 150 times. A few observations were made with a micrometer eyepiece formed of two achromatic lenses of a dividing microscope objective. This gave a magnifying-power of 228 times. Owing to the very low altitude of Jupiter higher powers could never be used in practice with any advantage, the planet's meridian altitude only slightly exceeding 20°, even in the south of England.

A filar micrometer by Troughton and Simms was employed for the purpose of measuring the latitudes of the belts and spots. It was not used for determining longitudes, partly because of the equatorial not having a driving-clock, and partly because it was considered that longitudes could be fixed with all necessary accuracy and much more easily by the method of eye-estimated transits. We now know that the latter method gives results equal in point of accuracy to the micrometric method. A number of measures of wide double stars were made in the years 1888 and 1889 with the object of determining the value in seconds of arc of the micrometer-screw. These measures have not up to the present time been reduced, as the measures for latitude are purely differential, and all that is necessary is to give the measured distances from the north and south limbs of the planet in parts of the micrometer-screw. There are no corresponding measures of the equatorial diameter of the planet; and even if there were, it is not likely that measures made with my little telescope could add anything of value to our knowledge of the polar and equatorial diameters of Jupiter, or the relative values of these two quantities. This work has been so thoroughly done with the many existing big telescopes as to make it simply waste of time for anyone to attempt anything similar with a small one.

For the purpose of fixing the longitudes and determining the rotation-periods of the spots the method of simple Eye-estimated Transits was made use of. In this method the time when a spot is observed to be exactly in mid-transit across the planet's disc is carefully noted as exactly as possible. The rotation of the planet is so rapid that the longitudes can

be fixed in this manner with as much exactness as they are by micrometer measures. Observations of this kind constitute what I have termed *direct transits*. In 1888 the times were usually recorded only to the nearest minute of time, though in a few instances greater exactness was used. Subsequent experience has shown that there is a distinct gain in the accordance of the observations by always noting the times to the tenth of a minute.

Besides the *direct transits*, a certain number of *double transits* were observed. That is, if the time is noted when two spots of the same kind d in the same latitude are at equal distances on either side of the central meridian of the disc, and also the time when one of the spots is in mid-transit, we obviously have the means of fixing the time of transit of the other spot. This latter time is then determined by what I have called *double transit*.

Finally, there are also some *estimated transits*, where the spot being a few minutes before or after mid-transit when observed, the time when that event occurred, or would occur, was simply estimated. This can be done with a considerable degree of accuracy, provided that the spot observed is not more than ten minutes before or after mid-transit. Neither the double transits nor the estimated transits can be expected to give results equal in point of accuracy to those obtained by direct transits, and they have not been made use of except when a direct transit is not available. They are, however, useful in some cases where, owing to interruption by clouds or for some other reason, the direct transit could not be observed.

The direct transits, as in the observations of 1887, were weighted at the time of observation according to a definite scale, ranging from 1 (very bad) to 5 (perfect satisfaction). Some of the observations weighted 1 are very rough indeed. The transits were all observed with the same eye, my right eye, and care was taken to always hold the head so that a line through the eyes was parallel to the direction of the belts. This is very easily done when the telescope is a Newtonian reflector with rotating tube.

The following abbreviations have been used to describe the size, brightness or darkness, and appearance of the spots and other markings. Those indicating size, brightness, and darkness form a definite and regular scale :—

List of Abbreviations used.

eL = exceedingly large.	vD = very dark.
vL = very large.	D = dark.
L = large.	mD = moderately dark.
mL = moderately large.	F = faint.
S = small.	vF = very faint.
vS = very small.	eF = exceedingly faint.
eS = exceedingly small.	v = very.
eeB = most exceedingly bright.	m = moderately.
eB = exceedingly bright.	def = defined.
vB = very bright.	p = preceding.
B = bright.	f = following.
mB = moderately bright.	n = north.
F = faint.	s = south.
vF = very faint.	irr = irregular.
eF = exceedingly faint.	R = round.
eeD = most exceedingly dark.	wh = white.
eD = exceedingly dark.	r = red, redness.

In addition to the foregoing abbreviations, R has been very frequently used to indicate the sidereal rotation-period of a spot, expressed in mean solar time; whilst Δ has been used to signify the distance of a spot or belt from the equator of the planet to either the north or south limb, corrected for the elevation of the Earth above the plane of Jupiter's equator, the semi-minor axis of the disc being taken as unity.

Besides the observations and measures of the spots and belts for longitude and latitude, the planet was drawn on each night of observation after the manner described on pp. 5 and 6 of Vol. I. of these Fragments. That is, every spot was drawn as it appeared when in mid-transit across the disc, and consequently when presented as near as possible in its true aspect, and unaffected by longitudinal foreshortening. Drawings made in this manner only require the addition of lines of latitude and longitude to constitute actual maps of the planet. I should much like to have reproduced all these drawings, but this has not been practicable. Since, however, the drawings will be carefully preserved, I have given in the last columns of the tables of observations of the spots in Section V. a reference to the drawing in which the spot appears, so that it will be easy at any time to trace the past history of any particular spot, should such be desired.

The longitudes of the spots have been given according to Marth's "Ephemeris for Physical Observations of Jupiter," published in the *Monthly Notices*, vol. xlviii. p. 68; the equatorial spots according to "System I.," and the extra-equatorial spots according to "System II." Neither of these two systems, it should be mentioned, corresponds to those in use at the present time. The following are the rotation-periods of the two systems :—

System I. $R = 9^h\ 50^m\ 15^s{\cdot}88.$
System II. $R = 9\ \ 55\ \ 40{\cdot}63.$

The rotation-period of System II. is the same as that used in the present Jovian ephemerides, but the zero of the longitude is different. The rotation-period of System I. is, however, quite different from that now in use, the latter being $9^h\ 50^m\ 30^s{\cdot}004$, or nearly fifteen seconds longer. These differences must be borne in mind when endeavouring to trace the past history of any spot or other marking.

The state of the definition or "seeing" has been noted at frequent intervals on each night of observation upon a scale ranging from 1 (worst possible) to 10 (perfect definition). Definition so bad as 1 has only rarely been recorded. On the other hand, one of 10 has never been reached in this climate, though one of 8 or 9 has been occasionally noted. Definition equal to 10 of the scale would mean that the image was absolutely sharp and distinct with all powers, and without so much as a quiver. With 8 or 9 the definition would be as sharp as with 10, but occasionally a slight quivering or unsteadiness would affect the image. Such nights are, however, rare in this climate. More usually the definition ranges from 2 to 6 or 7, and the change from one extreme to the other sometimes takes place quite suddenly. The scale value of the definition is not stated in the tables of observations of the spots in Section V., but it is frequently given in the subsequent Sections. The reason for this omission is that the effect of the quality of the seeing has already

been more or less discounted in the weights attributed to the transit observations.

It is necessary to say a few words on the subject of the interpretation of observations of planetary markings. Much has been written and said about this, and there seems to be a large amount of misconception or misapprehension on the subject. It would even seem to have been considered or assumed that we see, or ought to see, things as they really are. Nothing could well be much more erroneous. We never do see, nor are we ever likely to see, planetary markings as they really are. All that we ever do perceive is an impression produced by a conglomeration or more or less confused jumble of smaller details, too small or too indefinite or delicate, or too close together to be separately distinguishable. We never do see, nor can we ever hope to see, the ultimate structure of the markings. And in endeavouring to interpret our observations it is very important to bear three things in mind. Firstly, that several small dark * spots situated close together, and too small or too near one another to be seen separately, will or may appear to an observer as one apparently uniform dark spot or area. Secondly, that several small dark spots lying very approximately in a line, and too small or too close together to be separately distinguished, will or may appear as a more or less uniform and continuous dark streak. Thirdly, that when there are a number of very small dark detached spots scattered about on a bright surface, the eye of an observer can or may, consciously or unconsciously, join up several such spots, so as to give rise to the impression of the presence of more or less definite dark lines or streaks. The last two of these three things, although known before, were first clearly demonstrated, I believe, by the interesting experiments conducted by Mr. and Mrs. E. W. Maunder and Mr. J. E. Evans †. The first has rarely, however, been even obscurely alluded to, although it is not less important than the other two. But there is one point which I particularly wish to emphasise. That is, that in every case coming under these three heads there is an objective basis for what is apparently seen. It is a mistake, therefore, to speak of them as though they were purely subjective or altogether illusory or imaginary. Whether any particular streak or spot is to be regarded as being really a more or less continuous streak or area, or is to be referred to one of these three heads, must usually remain largely a matter of individual opinion; and each separate case must be considered on its own merits.

Most of those who have written upon the subject of the interpretation of observations and the visibility of streaks and lines seem to have overlooked, or disregarded or insufficiently considered, two very important factors, namely irradiation and contrast. As a consequence of the former of these —irradiation—a narrow dark streak on a bright surface will look narrower than it really is; and some eyes appear to be more affected by irradiation than others. Another effect of irradiation is to cause minor irregularities on the edges of a dark streak to appear smaller than they really are, or even if very small to vanish altogether. So that the total effect of irradiation is to cause a dark streak to look both narrower and more

* *Dark* spots have been referred to here, but the same considerations will apply more or less equally well to *bright* spots on a darker ground.

† See *Monthly Notices*, vol. lxiii. p. 488.

regular or even than it really is. Contrast, we know, may cause a small spot on a relatively large bright surface to appear as though it were almost if not quite black, although in reality it may be only slightly duller than the brighter surface around. And possibly this effect might be even more pronounced in the case of a narrow dark streak or line on a relatively large bright surface. Contrast, again, apparently affects some eyes more than others. Have we not here a more or less complete explanation of the different manner in which dark streaks, such as the canals of Mars, appear to different observers? To the observer whose eyes are the more sensitive to the effects of irradiation and contrast the canals would appear narrower and more regular than they would to one whose eyes were less sensitive. Hence one observer might very well describe a given canal as a comparatively broad, diffuse and perhaps even irregular streak, whilst another observer might see it as a narrow and almost black uniform line. Of all observers of Mars, Professor Percival Lowell seems to be the one who habitually sees and draws the canals as most linear. It would be interesting, therefore, if it could be ascertained whether his eyes are more sensitive to the effects of irradiation and contrast than are those of ordinary observers. Since irradiation must certainly, however, cause the canals to appear narrower than they really are, I am inclined to think that a recent estimate by Professor Simon Newcomb * of the total area of the canal-system of Mars as mapped by Lowell, deduced on other grounds, may not really be far from the truth after all. That is, that the area of the dark surface of the entire system of canals can scarcely be much less than half the total area of the planet.

But whatever may be the interpretation that can be put upon observations of planetary markings, there is one thing above all others that the conscientious observer should be most careful about; and that is to delineate and describe as exactly as possible that which he sees or appears to see. On no account should he try to see things as he thinks they ought to be seen; and still less should he strive to see things as others think that he ought to see them.

It should be mentioned that my eyes appear to be more sensitive to bright markings than to dark markings; so that if there were alternate white and dark areas in one of the zones of Jupiter I might very likely observe the light interspaces and call them *white* spots, although other observers might more particularly notice the dark intervals and describe the same as a succession of *dark* spots.

There is one other thing which should be referred to here—that is, the effect of aperture on the perception of planetary markings. Other things being equal, increase of aperture, both theoretically and practically, results in *minuter* details being rendered perceptible. But increase of aperture does not necessarily make a faint spot or marking of *large area* any plainer or more easily perceptible. There is no theoretical reason why it should, provided that the image is sufficiently bright with the smaller aperture. The perception of a faint spot or marking of large area is essentially the perception of faint contrasts, and the use of a larger aperture might even cause such an object to disappear, since by rendering visible some of the smaller and fainter details that were not perceptible

* *Astrophysical Journal*, vol. xxvi. p. 16.

with the smaller aperture, the general contrast of the whole area might be reduced or altered; and a large proportion of the planetary markings hitherto observed are areas of more or less considerable extent, particularly so perhaps those generally observed upon the planet Jupiter. There is no theoretical or practical reason, so far as I am aware, why the South Equatorial Belt of Jupiter, considered as a single streak or marking, should be any plainer with a 24-inch aperture than it is with a 12-inch aperture. The former would no doubt show minuter details about or in connection with the belt than the latter; but this is a different matter altogether. Hence it may be quite possible for a large, faint, indefinite spot to be more easily perceptible with a small telescope than it is with a large one, owing to the reduction or alteration of the contrasts resulting from the use of the larger aperture.

SECTION II.

ON THE DEGREE OF ACCURACY OF THE OBSERVATIONS FOR LONGITUDE.

Until quite recently it was supposed that the results obtained by the method of eye-estimated transits were much inferior in point of accuracy to those derived by the micrometric method, in which direct measures of the spots are made from the limbs of the planet with a micrometer. This idea, which is erroneous, seems to have arisen chiefly because no one had ever taken the trouble to properly compare the results obtained by the two methods. We now know that the results given by the method of transits are no whit inferior to those yielded by the micrometric method, so far as the accidental errors of the observations are concerned; whilst there is no reason to suppose that the latter method is less liable to systematic error than the former. Theoretically the micrometer should give the more accurate results, partly on account of the more exact bisection of the disc resulting from its use, and partly owing to its power of repetition. But in practice it is found that this theoretical advantage is masked or nullified by the circumstance that the markings which we have to observe are not round definite spots like star-discs, but spots of every degree of irregularity and non-uniformity *; and which spots, moreover, are in a more or less constant state of real change both in appearance and in position. There is consequently much uncertainty in the setting on such objects, the appearance of which is, moreover, liable to be prejudicially affected by the placing of a micrometer "wire" over them. There is also an additional source of uncertainty in the setting on the limbs of the planet, since one limb is commonly much duller than the other. It is not, however, proposed to consider this question generally here, but only the question of the degree of accuracy attained in the present series of observations.

With regard to this question there are several reasons why the degree of accuracy actually attained should be less than that attainable under favourable conditions. For, firstly, there is the low altitude of Jupiter in 1888. With a meridian altitude of only about 20° it is obvious that the majority of the observations must have been made with the planet at a considerably lesser altitude. The unsteady definition usually prevailing at such low altitudes must therefore have prejudicially affected the results. It should be mentioned that observations were made on every night that the planet was visible, and not only on selected nights when

* According to my experience it is most rare to see an exactly round or oval, and definite, or uniform spot on Jupiter, and even when seen they rarely preserve that aspect for more than a short period of time. The best delineations of the planet by other observers convey the same impression.

the seeing was, if anything, above the average. On many nights in 1888 the seeing was, as might be expected, exceedingly confused and unsteady; but on no night during the apparition were the observations discontinued on account of the badness of the definition, though, of course, on bad nights the fainter spots could not be observed, or, indeed, even seen at all.

Secondly, as already remarked, the times of transit were usually recorded only to the nearest minute of time, whereas subsequent experience has shown that there is a distinct increase in the accordance of the observations by noting the times to the tenth of a minute.

Thirdly, and this is perhaps the most important reason of all, there were no spots visible in 1888 really suitable under the conditions prevailing for exact observation. Exception may perhaps be taken to the remarkable dark southern spot *b*, and to two or three of the little dark spots in the northern hemisphere of the planet; but these spots, on account of their small size, were difficult to observe excepting on nights when the seeing was much above the average. And, moreover, being situated in comparatively high latitudes, they were, for this reason, also more difficult to observe. But the spots in general were all more or less indefinite and ragged or irregular on the edges, and not uniformly dark or bright, as the case might be. It should be mentioned in this connection that the spots are represented much more regular in shape and more definite in the Map of Jupiter forming Plate I. than they really were. This is partly owing to the general or average appearance being given in the Map, and this means that the minor irregularities, not always seen, are necessarily omitted. Another reason is that the time available for observing the appearance of any particular spot is very short, owing to the rapid rotation of the planet, and is, indeed, usually too short to enable an observer to make out and delineate the minor irregularities or details of the spots.

Lastly, there are the large real changes in appearance and position to which many spots are subject. Owing to this it has been necessary to discard altogether the equatorial spots and to confine ourselves to the extra-equatorial markings, in which the real changes are seldom so large or so sudden *.

In order, therefore, to ascertain the degree of accuracy of the present series of observations, the mean error of an observation † has been determined for several of the best observed and most suitable spots in each of the different zones of spots, omitting the equatorial markings. The following are the results:—

* The figures of Plate III. will give some idea of the changes of appearance to which the equatorial spots are subject, and Plates VII. and VIII. will indicate the abrupt changes of position which they undergo.

† As defined by Airy in his work on the 'Theory of Errors of Observations,' § 26, p. 19.

Apparent Errors of the Observations.

Spot.	Mean Error.	Number of Observations.
	(a) *Northern Spots.*	
	m	
Dark Spot Γ	±2·6*	11
Dark Spot Θ	±3·3	9
Dark Spot Σ	±2·3	7
Average mean error	±2·7	(3 spots.)
	(b) *North Tropical Spots.*	
White Spot C	±2·7	21
Dark Spot D	±2·1	17
White Spot D^2	±3·6	12
White Spot H	±3·3	14
White Spot L	±3·1	10
White Spot P	±2·2	12
Average mean error	±2·8	(6 spots.)
	(c) *The Red Spot.*	
Red Spot	±1·7	15
	(d) *South Temperate Spot.*	
Dark Spot δ	±2·6	10
	(e) *Southern Spots.*	
Dark Spot *a*	±3·8	8
Dark Spot *b*	±3·4	8
Average mean error	±3·6	(2 spots.)

The apparent errors of the two Southern Spots are rather large, as might be expected in the case of spots situated in so high a latitude. Omitting these two, the average mean error of an observation from all spots is $\pm 2^{m}\cdot 7$ (11 spots). But this is really too large, since in several cases there are clear signs that the motion of the spot concerned was not uniform. It is only necessary to refer to the spots Θ and H, where the evidence is clear that the motion was not uniform. In the case of either spot the magnitude of the residuals could be largely reduced by using a rotation-period varying slightly with the time. I think it may therefore

* Omitting the first two observations of this spot, the mean error is $\pm 1^{m}\cdot 7$.

be concluded that the average mean error of an observation in 1888 was $\pm 2^{m}\cdot 5$ for all spots. In the case of the Red Spot it was $\pm 1^{m}\cdot 7$, as stated above, and this probably represents the highest degree of accuracy attained in this year. Under more favourable conditions the average mean error for spots in general is about $\pm 2^{m}\cdot 0$.

The Rev. T. E. R. Phillips has recently called attention to the possible existence of a form of systematic error in eye-estimated transits of the Red Spot, or rather of the Red Spot hollow *. He found that the rotation-period of the Red Spot hollow was, on the average, $0^{s}\cdot 4$ shorter when derived from one opposition to another than when it was deduced from the observations of each opposition. This was from observations made in the years 1898 to 1904. My own observations of the Red Spot itself, made in a nearly corresponding period of time (1899 to 1904), show a similar difference, though larger in amount, namely $0^{s}\cdot 9$ †. Unfortunately the motion of the Red Spot, and of the hollow or bay, has been so irregular during the last eight years, that it is impossible to come to any definite conclusion on the subject from recent observations. Those of 1888, when compared with those of 1887, do not, however, favour the idea of the existence of a form of systematic error of the kind referred to. The longitude of the Red Spot, according to my observations, was about 349° at the end of the observations of 1887 ‡. This was also about its longitude at the beginning of the series of 1888, and likewise at the end. The existence of the suspected form of error is therefore not confirmed.

* *The Observatory*, 1905, p. 344. † *Ibid.* p. 390.

‡ See *Z. F.* vol. i. p. 96. My observations of the Red Spot in 1887 are most unsatisfactory, owing to the abnormal prevalence of easterly winds during the spring and summer of that year. This is apparent from the large proportion of transits bearing the low weight of 1.

SECTION III.

THE MICROMETRICAL MEASURES FOR LATITUDE.

The measures were always made from both the north and south limbs of the planet. Generally a complete measure consists of three or four double distances from each limb, but in the case of the two dark Southern Spots *a* and *b* there is only a single double distance from each limb. These spots were very difficult to measure, owing to their small size, and consequently the measures could only be effected in the instants of best seeing, so that time did not permit of a larger number of settings. It is important that measures for latitude should be made when a spot is near the central meridian of the disc.

In the list of measures which follows, the first column gives the date and the second and third the measured distances from the north and south limbs respectively, these distances being given in divisions of the head of the micrometer-screw. The fourth column contains the latitude deduced from these measures, and the fifth column the correction B for the elevation of the Earth above the plane of Jupiter's equator. In the sixth column is the reduced or true latitude, corrected for B, and the last column gives the longitude of the central meridian, according to System II., when the measures were made.

The question as to what kind of latitude it is advisable to adopt is an important one in the case of a planet like Jupiter, in which the polar compression is so great. A great many measures for latitude and the resulting latitudes, frequently without the actual measures, have been published, sometimes without any definite statement as to what kind of latitude has been adopted, or what formula has been used in the reduction. To add to the confusion here, it appears from a recent statement of Mr. A. C. D. Crommelin * that a wrong formula has been largely made use of, so that many of the published latitudes are presumably not true zenographical latitudes, as had been supposed.

Under the circumstances outlined above it seems pertinent to ask whether it is really necessary to go to the trouble of stating the results of such measures in either zenographical or zenocentrical latitudes. The positions of the belts and spots are required simply for locating these objects on the planet, or for comparison only, and they have never been used for any other purpose that I am aware of. Major P. B. Molesworth has published his own results without taking account of the polar compression, or as though Jupiter were a perfect sphere, and I have here followed his example, making use of the simple formula given by him †, namely,

$$\text{Sin } \phi = d/r.$$

* See *Monthly Notices*, vol. lxi. p. 115.
† See *op. cit.* vol. lxv. p. 696.

where d = the distance from the centre of the disc, and r = the polar radius of Jupiter; but of course correcting for the elevation of the Earth above the plane of the planet's equator.

Besides giving the latitudes derived in the above manner, I have also given the mean distance from the equator expressed as a decimal of the semi-minor axis of the disc. This manner of expressing the measured latitude is a convenient one; for most of the observations of Jupiter are made when the apparent polar diameter of the planet does not differ much from 40″. Since half of this, or 20″, would represent the semi-minor axis of the disc, it is obvious that 0·1 of the distance from the centre to either limb will correspond to about 2″ of arc; whilst 0·01 of this distance would be equivalent to about 0″·2 of arc, which is near the effective limit of accuracy with which measures of the markings on Jupiter can be made. The semi-axis minor of the disc can be divided into tenths pretty exactly by the eye. The symbol Δ has been used to indicate the latitude expressed in the manner above indicated.

Measures of the Belts, etc.

North Temperate Belt (middle).

Date.	N.	S.	Obs. Lat.	B.	True Lat.	Long.
1888.						
May 1	39·7	118·8	+29°·93	−3°·16	+26°·77	162°
June 1	41·0	119·0	+29·14	−3·11	+26·03	35
„ 10	37·4	117·7	+31·13	−3·08	+28·05	302

Mean Latitude = +26°·95; Δ = +0·453 (3 n).

North Equatorial Belt (north edge).

Apr. 13	55·8	106·3	+18·13	−3·16	+14·97	334
May 1	54·6	102·6	+17·76	−3·16	+14·60	113
„ 2	53·7	106·0	+19·09	−3·16	+15·93	257
„ 11	54·9	108·5	+19·15	−3·15	+16·00	228
„ 12	54·1	108·1	+19·45	−3·15	+16·30	285
„ 14	55·9	103·5	+17·40	−3·15	+14·25	274
„ 24	54·3	109·5	+19·69	−3·13	+16·56	296
June 2	53·9	107·5	+19·39	−3·11	+16·28	181

Mean Latitude = +15°·61; Δ = +0·269 (8 n).

South Equatorial Belt (south edge).

Apr. 20	95·8	60·7	−12·94	−3·16	−16·10	13
„ 26	96·4	61·3	−12·83	−3·16	−15·99	129
May 3	98·0	61·6	−13·18	−3·16	−16·34	48
„ 11	99·5	63·2	−12·88	−3·15	−16·03	171
June 1	98·0	61·4	−13·30	−3·11	−16·41	89

Mean Latitude = −16°·17; Δ = −0·278 (5 n).

Dark Southern Spot a.

Date.	N.	S.	Obs. Lat.	B.	True Lat.	Long.
1888. May 5	123·6	28·9	−38°·39	−3°·16	−41°·55	..

Latitude = −41°·55 ; Δ = −0·663 (1 n).

Dark Southern Spot b.

May 14	126·9	26·7	−40·69	−3·15	−43·84	..

Latitude = −43°·84 ; Δ = −0·693 (1 n).

The mean positions of the belts are given below, together with some of the results of Molesworth's recent measures * for the purpose of comparison. The positions of the North Temperate Belt and South Temperate Belt in 1890, as measured by Professor E. S. Holden on photographs of Jupiter taken at the Lick Observatory †, have also been added.

Belt.	Latitude in			
	1888.	1890.	1903–4.	1904–5.
S. Temp. Belt (centre)	....	−29°·08	−25°·93	−29°·59
S. Equat. Belt (S. edge) ..	−16·17	....	−14·67	−19·39
N. Equat. Belt (N. edge) ..	+15·61	....	+13·02	....
N. Temp. Belt (centre) ..	+26·95	+25·98	+26·35	+31·99

It will be seen from the above figures that there have been considerable changes in the latitudes of the belts. There is nothing new in this, for our knowledge of the existence of such changes dates back almost to the time of the invention of the telescope, but owing to them it is doubtful sometimes whether a belt seen in one year is identical with one visible in another. The two equatorial belts can always be correctly identified, but there is often much uncertainty with regard to the fainter belts. So far as regards the observations of 1888, it seems doubtful whether the narrow discontinuous belt in the latitude of the southern edge of the Red Spot, or a broader though also discontinuous belt lying somewhat farther south, is to be regarded as the same belt as the South Temperate Belt of the last few years. I have called the former of the two belts, that is the narrow belt with numerous spots in the latitude of the southern edge of the Red Spot, the South Temperate Belt; but there is considerable uncertainty as to whether it is really identical with the South Temperate Belt of recent years.

* See *Monthly Notices*, vol. lxv. pp. 102–3, and vol. lxvi. p. 104. The means of the May and December means have been taken for 1903–4.

† *Monthly Notices*, vol. li. p. 404.

SECTION IV.

CHART OF JUPITER; NOMENCLATURE OF BELTS, ETC.; GENERAL APPEARANCE OF THE BELTS AND MARKINGS IN THE APPARITION OF 1888.

The Chart of Jupiter forming Plate I. was constructed in the same manner as was that for the previous apparition of 1887 *. That is, the spots and markings are shown in the relative positions which they would have occupied at the date of opposition (1888, May 21), the proper motions of the individual spots having been taken into account. For the purpose of the Chart it has been assumed that the zero of System I. corresponded to longitude 50° in System II. at the date of opposition.

The system of nomenclature adopted for the chief belts and light zones is that used, and I believe devised, by the late Rev. W. R. Waugh, the first Director of the Jupiter Section of the British Astronomical Association. The diagram, fig. 1, Plate II. will make it clear. As this system of nomenclature has now been very generally adopted all over the world, it is much to be desired that all other observers should conform to it, as thereby a good deal of confusion, and perhaps in some cases misapprehension, would be avoided. It is also a most convenient system in practice, as the belts etc. can be concisely referred to by the initial letters of their names: for example, the North Equatorial Belt by NEB; the North Temperate Belt by NTB; and so on.

But, as already mentioned, even when using this or, for the matter of that, any other system of nomenclature, there is sometimes doubt or uncertainty as regards the identity of the fainter belts. The two great equatorial belts can always be readily identified with the bright equatorial zone, and the north and south tropical zones. But there is occasionally a little uncertainty as regards the identity of the North Temperate Belt; and likewise, as we have seen, with regard to that of the South Temperate Belt. This is due partly to real changes in the latitude or position of the belts, and partly to changes in their appearance. There is a tendency sometimes for a narrow belt to die out and disappear, and for a new belt to make its appearance later on in nearly though not exactly the same latitude. There is also some evidence suggesting there may sometimes be a progressive shift in the latitude of the fainter belts—those in the northern hemisphere, for example, shifting southwards towards the equator, but dying out before reaching the North Equatorial Belt; and new belts making their appearance from time to time in the region thus left vacant towards the north. But the evidence on this question is by no means conclusive at present.

The change in the system of nomenclature of the belts now adopted has produced some changes in the names given to the different series of spots. Thus, the North Temperate Spots of 1887 become the North Tropical Spots of 1888; the Southern Spots of the former year become the South Temperate Spots of the latter; whilst in 1888 the designation of Southern Spots is

* *Z. F.* vol. i. pp. 8 & 9.

confined to the markings situated considerably farther south than any observed in 1887.

Coming now to the general appearance of the belts and markings in 1888, this will be gathered better from inspection of Plate I. than from any verbal description. But, as already mentioned, it is necessary to remember that the spots and other markings are shown with a decided unreal uniformity of aspect, simply because their *general appearance* only is represented. Hence minor or temporary irregularities are necessarily usually omitted. The changes from day to day, or the temporary irregularities, were particularly great in the case of the equatorial markings. The actual spots, moreover, all over the disc were, almost without exception, much more indefinite and irregular than they appear in the Chart. A certain amount of conventionality of style too is unvoidable in work of this kind ; as if a faint, indefinite marking is drawn exactly as it appeared it might very likely be lost altogether in the process of reproduction. Hence such a marking is of necessity rendered both more definite and more regular than it really was.

The leading features in 1888 were the two very broad and double equatorial belts. With regard to these, the representation of the central rifts as continuous straight bright streaks or rifts is in particular a conventional one. It represents the appearance passably only as seen when the definition is exceedingly bad and confused. Under better conditions the central rifts are very different, being really highly complex, and formed by narrow, brilliant, winding channels with many brighter spots or condensations and other irregularities, and with numerous tributary bright rifts breaking through or penetrating into the dark material of the belts. The whole sometimes forms part of a complex structure of the belts, similar to that which has been described by Terby in his Third Memoir.

Comparing the present Chart with that constructed from the observations of 1887 *, we notice that there is a strong general resemblance between the two. Two chief differences are that the North Temperate Belt, double in 1887, was never seen otherwise than single in 1888 † ; and that there is a great development of the dark wisps having a meridional direction in the bright equatorial zone. The equatorial wisps are separately considered in Section XI., so that it is unnecessary to refer to them more particularly here, beyond stating that the development of the meridional wisps took place chiefly in the latter part of the apparition, the oblique wisps at the same time apparently dying out. This formed part of a general change in the aspect of the equatorial region of Jupiter, such change reaching its climax a year or two later.

A third important change is due to a number of little dark spots making their appearance on the three narrow belts in the northern hemisphere of Jupiter, and in evident connection with them some faint dusky streaks having a general meridional direction, and extending for a long distance towards the north pole, certainly as far north as north latitude 60°. The presence of the two little dark spots *a* and *b* in an unusually high southern latitude constitutes a fourth important change.

* *Z. F* vol. i. plate i.

† Denning, however, shows it double in a drawing dated 1888, Feb. 12 (*Journal Liv. Astr. Soc.* vol. vi. p. 141).

SECTION V.

OBSERVATIONS OF INDIVIDUAL SPOTS, WITH REMARKS ON THEIR MOTIONS AND CHANGES.

This Section contains the details of the observations for longitude, or rotation-period, of the different markings, together with the results derived from the discussion of the same. The arrangement of the various tables of observations will be very easily understood. The first column contains the date; the second the Greenwich mean time of the transit; the third the weight attributed to the observation on the scale of 1 to 5; the fourth the resulting longitude of the spot, according to System I. of Marth's Ephemeris for the equatorial, and according to System II. for the extra-equatorial spots. The fifth column contains a short description of the marking observed, using the abbreviations of the list in Section I. The last column gives a reference to the original drawing in which the marking appears.

For each Sub-section* a Chart is given showing all the observations relating to the markings to which the same has reference. This is considered very important, for these Charts show at a glance not only the accordance of the observations, but, what is more important, the nature and correctness of the identification of the different spots, and the changes in position or motion which they underwent. In work of the kind with which we are now concerned we may enumerate the following general fundamental principles or rules to be followed:—

(i.) That the observations of the different spots should be correctly identified.

(ii.) That the spots observed should be as numerous as possible.

(iii.) That there should be as many observations as possible of each spot.

(iv.) That the observations of each spot should extend over as long an interval of time as possible.

(v.) That the observations should be as accurate as possible.

The foregoing fundamental principles are given in what I consider to be their order of importance, though it may differ somewhat widely from the order which some observers of Jupiter might adopt. This is particularly the case with reference to the last principle, which some observers might be inclined to put first. But the reason for putting this last instead of first is, I believe, too strong to be withstood †.

* Excepting that the observations of the Red Spot, of the South Temperate Spot δ, and of the Southern Spots are all shown upon the same Chart.

† I particularly do not wish to be understood as underestimating or undervaluing the importance of making the observations with as much exactness as possible. What I do want to make clear is that, owing to outside causes, extreme accuracy in the observations is less important than some other desiderata; for when the rotation-periods of adjacent spots differ by a number of seconds it must be obvious that an increase in accuracy of a tenth or two of a second in the rotation-period of an individual spot is comparatively unimportant.

For it must be borne in mind that we are not dealing with fixed points on the solid surface of the planet. So far is this from being the case, that each and every individual marking on Jupiter may be said to have its own peculiar proper motion, or period of rotation, and in most cases such proper motion or period of rotation is not even a constant one. Even when we have a number of similar spots in the same latitude, it is found that the individual spots have rotation-periods differing by several seconds at least from each other; and this is the case whether the observations are made by the method of eye-estimated transits or by direct micrometer measures. In fact we cannot do better, in order to show the nature of the problems with which we have to deal, than to adduce the results derived by Professor G. W. Hough from some of his micrometer measures. The following, for example, are the rotation-periods of spots in the North Tropical region derived from the micrometric measures of this observer in the opposition of 1894–5*:—

North Tropical Spots observed by Hough in 1894–5.

		h	m	s
Black Spot *a*	R =	9	55	22·8
,, ,, *b*	,, =	9	55	30·0
,, ,, *c*	,, =	9	55	36·6
,, ,, *d*	,, =	9	55	38·1
,, ,, *e*	,, =	[9	55	49·1]
,, ,, *f*	,, =	9	55	34·25†
White Spot a_o	,, =	9	55	23·2
,, ,, c_o	,, =	9	55	38·1
,, ,, d_o	,, =	9	55	38·4
,, ,, *m*	,, =	9	55	40·1†
,, ,, *n*	,, =	9	55	25·4
Mean	=	9	55	32·69 (10 spots).

The mean value of the seconds of R is 32·69, but we have variations ranging from $9^s{\cdot}89$ on one side of the mean to $7^s{\cdot}41$ on the other, omitting the abnormally large result for spot *e*, because it is based on only three observations with a gap of nearly two months, so that the identification is uncertain. I venture to think that no one studying the above figures can fail to be impressed by the comparative unimportance of extreme accuracy in the observations! What practical difference would result by an increased exactness of a few tenths of a second in any one of the above values of R? It is obvious that each spot has its own peculiar proper motion or rotation-period, and that whilst all the spots partake more or less of the motion of the same great current, there are local variations in the rate of the motion or drift of this current. Yet by taking the mean of the rotation-periods of a number of spots in the same latitude, or current, we can eliminate to a great extent the effect of these local variations. We may be sure that the mean value of Hough's 10 determinations represents closely the actual rate of drift of the North Tropical current in 1894–5.

* *A. N.* 3354.

† Mean of the two deduced periods.

If the spots were fixed to the solid surface of the planet, we should have no option but to consider the accuracy of the observations as of the very first importance. But, as we have seen, the individual proper motions of the spots in the same latitude are so diverse as to greatly exceed any possible errors in the observations; and it is, in fact, seldom necessary to devote much time to the computation of the rotation-period of an individual spot, so as to obtain out of the observations all the accuracy that they are capable of giving. It is, almost without exception, pure waste of time and labour to calculate the rotation-period of any one spot by an elaborate least square reduction of the observations.

But what is of far greater importance than extreme accuracy in the observations is that there should be as many spots observed as possible in the same latitude. For by combining the rotation-periods of a number of such spots we shall, as already stated, eliminate in great measure at least the effects of the individual proper motions, and obtain a result which we may regard as representing very closely the rotation-period of the surface material of the latitude in question. For this reason I place the number of spots observed next after what I consider to be the most important principle of all—that is, as already stated, that the observations of the individual spots should be correctly identified.

It must be remembered that spots possessed of such a characteristic aspect that they can be infallibly recognized simply by their appearance are rare. The great Red Spot; the peculiar little reddish spot known as the "Violin" spot, which made its appearance a few years ago; and the present South Temperate Disturbance, may be instanced as examples of markings of this kind. But, generally speaking, the spots have a great family likeness, particularly those which are situated in the same latitudes, so that it is usually difficult, if not impossible, to identify them with certainty by their appearance alone; not to mention the fact that in some latitudes the individual spots undergo great changes in their appearance in the course of a few days.

The importance of correct identification can, perhaps, be best appreciated by turning to Plate VIII., which shows all the observations of the South Equatorial spots. It is not difficult to place a straight rule almost anywhere, or in any direction, across this Chart so that it would nearly cut through four or five or even more of the dots or circles representing the observations. Yet any such identification derived in this manner would be obviously in most cases quite erroneous, although the four or five observations might appear to be very accordant. In other words, an identification based only on four or five apparently very accordant and accurate observations may be in reality quite incorrect. To add to the difficulty, the equatorial spots undergo great changes within a few days, so that a very bright spot seen on one night may be comparatively faint a few nights later; whilst a faint spot not far off may have become very brilliant. I venture to think that a careful inspection of Plate VIII. will satisfy most people not only of the primary importance of correct identification, but also that it is very important that the observations should be as numerous as possible, since it is only by having many observations available that we can be certain of the correctness of our identifications.

There is one additional general rule which I have found very helpful in

identifying the different spots, particularly those situated in the equatorial regions of the planet. This is, that the white spots do not pass or cross over or under the dark ones, and *vice versa*. For whenever the observations are very numerous we find that if a white spot, for example, undergoes a shift of longitude, the adjoining dark spot experiences a similar shift. This rule, although a great help in the work of identification, must not be taken as infallible however. In the present series of observations there is strong evidence showing that the dark North Equatorial spot 24 *a* passed from one side to the other of the white spot 23.

(i.) The Northern Spots.

In 1887 no spots were observed on or to the north of the North Temperate belt, but after the observations of 1888 had been in progress for some time two little nearly round blackish spots were observed on the North Temperate belt and the next belt to the north of the same. These constitute the spots designated Γ. They were first seen on May 2 *. It is well known that an eruption of small blackish spots occurred in 1880 on the North Temperate belt, which spots were remarkable as having the shortest rotation-periods of any markings hitherto observed upon Jupiter, namely about $9^h\ 48^m$ only, or nearly eight minutes shorter than that of the Red Spot. It was therefore very important to ascertain as soon as possible whether or not the newly formed spots had a similar abnormally quick motion, or whether they rotated at approximately the same rate as the Red Spot. This question was quickly settled by observations of the same spots on the following night, May 3, although the planet had made only two rotations in the interval. Since the pair of spots preserved the same position as before relative to the Red Spot, it was clear that they rotated at approximately the same rate as that object; since if they had rotated as quickly as the quick-moving spots of 1880, there would have been a relative displacement equivalent to something like sixteen minutes in the time of transit in the course of two rotations of the planet.

Very shortly after this quite a number of similar spots were observed on the two narrow belts above referred to, with in some cases a third companion spot on the narrow belt still further to the north. But in most cases they should be described as thickenings of the belts rather than as spots properly so called, and even the two spots Γ became more elongated and less spot-like as the time went on.

But what is somewhat remarkable is that in most cases there was also a dusky streak extending in a north and south direction through the different spots of each little group. These streaks gave a very peculiar appearance to the northern hemisphere of the planet, as when several of them were in sight together the streaks appeared as though they radiated from the north pole of the planet, like broad meridian lines. This appearance is represented in Plate II. fig. 2. In some cases the streaks extended southwards across the North Tropical zone to dark spots on the north side of the North

* Two of the spots Θ had, however, been seen as early as April 6, but they were not re-observed until May 13; and they were, moreover, very much extended, so as to be rather narrow thickenings of the belts than spots properly so called.

Equatorial belt; and northwards they certainly extended as far as north latitude 60° *.

It is evident from the long-continued existence of these spots and streaks that the entire surface material of the planet between the north edge of the North Equatorial belt (that is, north latitude 12°) and north latitude 60° must have been rotating in very nearly the same time in 1888, as otherwise this peculiar arrangement must have been more or less quickly broken up. And this time is very nearly the same as that of the Red Spot, the mean rotation from nine spots being $9^h\ 55^m\ 39^s{\cdot}43$.

The appearance presented by these streaks was so regular and peculiar as to make one think that they were not real, but due to some species of illusion. But there can be no doubt of their real existence, for they only appeared as apparently straight north and south streaks when near the central meridian of the disc. At other times they were more or less inclined to that meridian, as roughly indicated in Plate II. fig. 2, and their angle of inclination was constantly changing as they moved across the disc. Moreover, somewhat similar streaks were photographed at the Lick Observatory some years later. Hence the hypothesis that the streaks were purely apparent or illusory, or due to the eye of the observer linking up or connecting together several dark spots close together and nearly in a straight line, does not seem tenable.

All the observations of these Northern spots are shown in Chart form

Dark Northern Spots Γ.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 2	14 50	3	0·2	2 nearly R blackish spots.	165
„ 3	10 40	1	359·5	Seen indistinctly through cloud.	166
„ 10	11 37	2	6·8	2 S spots.	170
„ 12	13 17	2	8·0	2 S spots.	173
„ 14	14 15	2	8·0	2 S D spots.	176
„ 20	29 53·5	1	8·2	Def v confused.	179
„ 24	13 05	1	5·6	2 S v delicate spots.	183
„ 27	10 35	1	6·1	2 S D spots.	186
June 1	9 43·5	2	6·9	2 S spots with F D streak.	190
„ 3	11 22	2	7·1	2 S spots joined by F shading.	192
„ 10	12 05·5	1	6·0	2 S D spots.	193
„ 13	9 32	2	4·2	2 S spots with F streak.	195

* Fig. 2, Plate II. only roughly represents the appearance of the streaks apparently radiating from the planet's north pole, and it is a purely imaginary diagram. The various drawings do not show the streaks extending north of the belt in latitude about +39° (see Plate I.), but I am certain that they actually extended much farther north than this belt. Indeed the streak through spots Θ is expressly described as extending northwards almost to the pole on May 15.

R=9^h 55^m $40^s{\cdot}7$ (101 rotations). The following are the residuals O−C according to the above period:—

Date.	O−C.	Date.	O−C.
1888.	m	1888.	m
May 2	− 9·7	May 24	−0·9
„ 3	[−10·9]	„ 27	0·0
„ 10	+ 1·1	June 1	+1·3
„ 12	+ 3·2	„ 3	+1·7
„ 14	+ 3·2	„ 10	−0·3
„ 20	+ 3·5	„ 13	−3·2

in Plate V., lines being drawn connecting the observations of the same spots. The connecting lines, both here and in the other Spot Charts, are continuous when the identification appears certain, but dotted when it is doubtful. The different Northern spots, or rather groups of spots, are here separately considered in order of increasing longitude.

The mean error of an observation of the spots Γ is $\pm 2^m{\cdot}6$, omitting that of May 3; or $\pm 1^m{\cdot}7$, omitting both May 2 and May 3. The difference of the first two observations from the rest is probably due partly to real change in the spots, and partly perhaps to a different reference point being taken. When the spots were first seen they were nearly round, and the northernmost one was some distance preceding the other. But later on they had acquired a more elongated shape, and the northernmost spot only slightly preceded the other. It is not unlikely that the two spots may have been observed as one mass on May 2 and 3, whilst subsequently the southernmost and plainest spot alone may have been observed for longitude.

Dark Northern Spots Δ.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
June 30	9 30±	..	38·3±	2 S D spots.	201
July 19	10 18	..	41·8	2 m plain D spots and streak.	208

Observations insufficient to determine the rotation-period.

Dark Northern Spots Θ.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 6	16 05	2	95·3	2 darkenings and thickenings of the belts.	148
May 13	11 19	1	87·1	S D spot on NTB.	174
„ 15	12 59	1	88·4	2 mD thickenings of belts and D streak nearly to pole.	177
„ 20	12 02	1	85·9	2 slight darkenings and thickenings of belts.	179
„ 25	11 01	2	81·0	2 S mD spots, the streak betw. being quite D.	184
June 1	11 48	3	82·6	2 rather S mD spots connected by D shading.	190
„ 11	10 03·5	1	82·6	S mD spot on NTB, companion on belt north suspected.	194
„ 16	9 13	1	83·7	2 S delicate D spots with D shading between.	197
„ 30	10 46	2	84·2	2 S mD spots with mD streak.	201

R=$9^h\ 55^m\ 35^s{\cdot}2$ (205 rot.). These were two swellings or thickenings of the two belts rather than spots properly so called. On May 15 the dusky streak through them seemed to extend almost to the north limb of the planet. The following are the residuals given by the above period :—

Date.	O−C.	Date.	O−C.
1888.	m	1888.	m
Apr. 6	+5·2	June 1	−4·4
May 13	−0·3	„ 11	−1·6
„ 15	+2·3	„ 16	+1·7
„ 20	−0·7	„ 30	+5·5
„ 25	−7·8		

The mean error of an observation is $\pm 3^m{\cdot}3$, but the motion of the spot, or spots, was clearly not uniform, and the residuals might be largely reduced by adopting a rotation-period varying slightly with the time.

Dark Northern Spots A.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 11	10 29	2	116·1	S mD spot on NTB with comp. spot n.	171
,, 15	13 49	1	118·6	2 rather S delicate spots.	177
,, 20	12 51	1	115·5	The northernmost spot not seen.	179
June 16	10 02	2	113·3	2 S mD spots joined by F shade.	197

R = $9^h\ 55^m\ 36^s{\cdot}2$ (87 rot.).

Dark Northern Spots Ξ.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 21	10 50±	..	192·8±	A D and well def thickening of the NTB.	180
,, 23	12 27	..	192·2	Time very approximate.	182
Aug. 23	8 33	1	193·8	2 v delicate S spots.	211

R = $9^h\ 55^m\ 41^s{\cdot}2$ (227 rot.). The spots were also seen on June 14, so that, taking all things into consideration, there does not seem to be any probability of a mis-identification.

Dark Northern Spots Π.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 26	11 03	2	232·7	Rather S mD spot on NTB.	185
June 2	11 47	2	231·9	Rather S F spot on NTB, spot farther n not seen.	191
,, 14	11 35	1	228·9	Both spots seen indistinctly.	196
July 6	9 51·5	2	232·8	Spot on NTB only seen certainly.	203
,, 18	9 27	2	220·9	2 pretty plain rather S spots, with a plain streak.	207

R = $9^h\ 55^m\ 36^s{\cdot}2$ (128 rot.). The last observation differs considerably from the rest, perhaps owing to the two spots having been observed as one mass, the other observations referring to the plainer spot on the NTB alone.

Dark Northern Spots Σ.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 14	11 48	3	255·0	S D spot on NTB with a smaller spot on the belt n.	176
„ 21	12 32	1	254·5	F delicate spot on NTB, with companion spot n.	181
„ 24	10 01	2	254·4	2 vS D spots, n spot the fainter.	183
„ 26	11 33	2	250·8	S mD spot on NTB, a fainter companion spot n.	185
June 17	9 41	3	251·0	2 rather S spots.	199
July 6	10 25	2	253·1	2 S mD spots, that on the NTB being the plainer.	203
„ 23	9 24	2	250·1	2 rather S mD spots.	209

R = 9^h 55^m $37^s·95$ (169 rot.). The following are the residuals :—

Date.	O−C.	Date.	O−C.
1888.	m	1888.	m
May 14	+1·0	June 17	−1·9
„ 21	+0·9	July 6	+3·6
„ 24	+1·0	„ 23	+0·4
„ 26	−4·7		

The mean error of an observation is ±$2^m·3$.

Dark Northern Spots Υ.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 14	12 32	3	281·6	A thickening and darkening of the NTB.	176
„ 21	13 12	2	278·6	mD spot on NTB, fainter spot n.	181
June 17	10 37	2	284·9	F and delicate. Perhaps 3 spots.	199
„ 22	9 42	2	283·2	A distinct spot on NTB.	200
Aug. 31	7 49	1	288·0	Spot on NTB plainly glimpsed.	213

R = 9^h 55^m $43^s·3$ (263 rot.). Besides the chief spot on the NTB fainter companion spots were seen more or less distinctly on the two narrow belts farther north. The dark streak through the spots to the NEB was visible for $2\frac{1}{2}$ months.

Dark Northern Spots Φ.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 12	11 15	2	294·3	A delicate darkening and thickening of the NTB.	173
„ 24	11 20	1	302·1	2 S mD spots joined by F D shading.	183
„ 31	11 43	2	[288·7]	F spot on NTB*.	188
June 10	10 15·5	2	299·5	S F v delicate spot on NTB.	193
„ 17	11 02	3	300·0	Pretty plain spot on NTB, 2 others suspected.	199

R = $9^h\ 55^m\ 41^s{\cdot}6$ (87 rot.). The spot was also seen plainly on July 16, with the companion spot north of the chief spot. On June 17 a third spot was suspected still farther to the north.

Dark Northern Spots Ψ.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 10	10 28	1	325·1	Not well seen.	170
„ 14	13 49	3	328·2	S vF spot on NTB.	176
„ 24	12 08	1	331·1	2 S delicate spots with F streak.	183
June 10	11 07·5	1	330·9	2 spots faintly glimpsed.	193

R = $9^h\ 55^m\ 46^s{\cdot}8$ (75 rot.). The dark streak running through the two spots was in this case considerably inclined to the meridian.

Summary of Northern Spots.

Spot.	Rot.-Per.	No. of Rot.	No. of Obs.
	h m s		
Dark Spots Γ.....	9 55 40·7	101	12
Dark Spots Δ.....	.....	..	2
Dark Spots Θ.....	9 55 35·2	205	9
Dark Spots Λ.....	9 55 36·2	87	4
Dark Spots Ξ.....	9 55 41·2	227	3
Dark Spots Π.....	9 55 36·2	128	5
Dark Spots Σ.....	9 55 37 95	169	7
Dark Spots Υ.....	9 55 43·8	263	5
Dark Spots Φ.....	9 55 41·6	87	5
Dark Spots Ψ.....	9 55 46·8	75	4

Mean Rotation-Period of Northern Spots = $9^h\ 55^m\ 39^s{\cdot}43$ (9 spots).

* It is doubtful whether this observation does not belong to the preceding spot Υ rather than to Φ.

Following the principle already laid down, that the number of spots is more important than the exactness of an individual result, the above determinations were given equal weight in forming the mean, excepting the last two results, which were given half weight.

(ii.) The North Tropical Spots.

The general appearance of the North Tropical zone, and the northern part of the North Equatorial belt, in 1888 was almost exactly similar to what it was in 1887, and calls for little in the way of remark. As in 1887, there were numerous dark but more or less indefinite and irregular masses on the north side of the North Equatorial belt, projecting northwards into the bright North Tropical zone. Whilst in the latter zone, and on the north edge of the North Equatorial belt, were many brilliant white spots, frequently indenting or apparently penetrating into the dark belt; but, excepting where sharply bounded by this belt, these spots also were generally indefinite and irregular.

The appearance of the North Tropical zone (and north part of the North Equatorial belt) above described is, however, extremely interesting in one respect, namely, as illustrating what may be called *persistence of type*. It is not uncommon for a particular type of appearance to characterise certain regions of Jupiter for several years, and then more or less gradually or suddenly, as the case may be, to merge or change into a totally different type of appearance. The North Tropical region (including here in this term the North Tropical zone and the northern half of the North Equatorial belt) has during the last quarter of a century been a particularly good illustration of this persistence of type. Between 1880 and 1883 the region was practically devoid of conspicuous markings, the north edge of the North Equatorial belt being comparatively straight and free from irregularities. But after 1883 numerous conspicuous bright and dark spots made their appearance on the north side of the North Equatorial belt, and the whole region soon merged into the type characteristic of 1887 and 1888. This type itself, as the observations of subsequent years will show, in its turn changed into types of a totally different kind. One of these may be instanced as an example, because it will be familiar to many recent observers of Jupiter, namely that characterised by the appearance of oval-shaped detached spots, quite separated from the North Equatorial belt, such as the spots known by the names of the "Violin" spot and the "Garnet" spot *.

Practically the only difference of importance in 1888, as compared with 1887, is that in the former year some of the peculiar dusky streaks from the Northern spots extended southwards across the bright North Tropical zone to dark spots on the north side of the North Equatorial belt.

Several of the spots seen in 1888 are certainly identical with spots observed in the previous year. Where the identity seems pretty certain these spots bear the same letter which was assigned to them in 1887. The identity appears to be quite certain in the case of the following spots: C, D, D_2, L, and P, notwithstanding that a considerable change had occurred in the rate of motion of most of these spots.

All the observations of the North Tropical spots are shown in Chart

* These names, which were originally bestowed by Mr. Leo Brenner, of Lussinpicolo, admirably describe the general appearance of the two spots in question.

form on Plate VI., from which the general accordance of the observations and the all-important question of correct identification will be apparent at a glance.

In discussing the results of 1887 * attention was called to a very remarkable circumstance, namely, that on one side or hemisphere of Jupiter the North Tropical markings rotated in a period nine seconds longer than those on the other side or hemisphere. Thus, the nine spots in longitude 45° to 160° gave a rotation-period of $9^h\ 55^m\ 32^s{\cdot}2$, and the eight spots in longitude 170° to 330° one of $9^h\ 55^m\ 41^s{\cdot}3$. The observations of 1888 show that the motions of the swifter-moving spots received a check, so that in this year the surface material in the North Tropical region all round the planet rotated at nearly the same rate, the mean rotation-period in 1888 being $9^h\ 55^m\ 39^s{\cdot}92$, from fifteen spots †.

White North Tropical Spot C.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 25	14 07	3	19·7	mL, vB, conspicuous.	141
Apr. 1	14 56	1	21·8	B, well def, oval.	143
„ 3	16 33	3	21·2	mL, vB, well def, oval.	144
„ 6	13 53·5	4	15·8	mL, vB, well def, conspicuous.	147
„ 13	14 41·7	4	17·6	mL, eB, well def, oval.	152
„ 20	15 27	5	17·7	eB, nearly R, well def, est 1½″ in diam.	155
May 3	11 04	3	14·0	mL, nearly R, well def, vB, like a satellite.	166
„ 10	11 57	4	18·9	vB, nearly R, v conspicuous, ylsh.	170
„ 12	13 30	3	15·9	Rather S, vB, well def, nearly R, B extension p.	173
„ 14	15 09	3	16·5	Rather S, nearly R, vB, disc-like.	176
„ 15	11 11	2	23·1	Rather S, B, nearly R.	177
„ 19	14 17·5	3	18·0	Rather S, nearly R, eB.	178
„ 20	10 10·5	3	18·5	vB, nearly R, bright region p.	179
„ 24	13 25	1	17·6	Rather S, vB, well def, oval.	183
„ 27	10 48	3	14·0	Rather S, vB, oval, ill def brightness p.	186
June 1	9 59	4	16·3	mL, eB, nearly R, disc-like.	190
„ 3	11 38	2	16·8	mL, vB, scattered brightness around.	192
„ 10	12 20·5	2	15·0	mL, vB, nearly R, bright region p.	193
„ 13	9 49	5	14·5	Rather S, vB, nearly R, well def, ylsh, bright radiations round.	195
„ 22	12 13	1	14·4	mL, B.	200
July 19	9 30	1	12·8	mL, B.	208
Aug. 22	7 45	est	14·6	mL, vB, nearly R.	210

* *Z. F.* vol. i. p. 18. It should be remembered that in this volume the North Tropical spots are termed North Temperate spots.

† See Note * on next page.

R=9^h 55^m 38^s·8 (362 rot.). The following are the residuals O − C, according to the above period :—

Date.	O − C.	Date.	O − C.
1888.	m	1888.	m
Mar. 25	+ 0·6	May 19	+1·9
Apr. 1	+ 4·5	„ 20	+2·7
„ 3	+ 3·7	„ 24	+1·6
„ 6	− 4·9	„ 27	−4·3
„ 13	− 1·5	June 1	−0·1
„ 20	− 0·8	„ 3	+0·9
May 3	− 6·0	„ 10	−1·5
„ 10	+ 2·6	„ 13	−2·2
„ 12	− 2·2	„ 22	−1·5
„ 14	− 1·0	July 19	−2·2
„ 15	+10·0	Aug. 22	+3·3

The mean error of an observation is ± 2^m·7. But although a conspicuous and a comparatively well-defined object, this spot was really not definite enough for very exact results. In particular there was much diffuse brightness for a considerable distance preceding the spot proper. Generally a more or less well-defined nucleus was visible, but it is likely that this nucleus was not always in the same position. It was sometimes described as being very definite, a brilliant disc, like a satellite when just entering on the planet's disc. But in poor seeing it is probable that more or less of the fainter bright surface around was observed with the nucleus.

This spot C is undoubtedly the same as the spot of the same name observed in 1887 †. The longitude on June 22 of the latter year was 66°·4, and the rotation-period 9^h 55^m 32^s·6 ; so that the computed longitude on March 25, 1888, is 12°·2. The actual observed longitude is 19°·7, the difference being equivalent to barely 13^m in the time of transit ; and the spot was an extremely brilliant one in both years, so that there can be no doubt as to the identity of the object, notwithstanding that its rotation-period in 1888 was 6^s·2 longer than it had been in 1887. It is probable that the change in the rate of motion of the spot occurred pretty suddenly shortly before the 25th March, 1888.

* A better example of a different rate of motion in the same latitude, but in different longitudes, has been described by Phillips in the *M. N.* vol. lx. p. 214 and plate 6. It is interesting to note how the swifter-moving spots apparently died out as they approached the slower ones, fresh or new spots making their appearance to take their place at the following side of the region of the swift-moving spots. Another and perhaps equally good example of this remarkable feature occurred on the planet Saturn in 1894 (see *M. N.* vol. lv. p. 366 and plate 7). Here there were three distinct groups of Equatorial spots rotating at different rates, and the difference of rotation-period amounted to over half a minute. It is interesting to note how the swifter-moving spots died out, fresh or new ones making their appearance to take their places, in exactly the same manner as described by Phillips in 1899 in respect of the North Tropical spots on Jupiter.

† *Z. F.* vol. i. p. 21.

The history of spot C dates back, however, much earlier than 1887, since the object was first seen on Jan. 27, 1885, by Denning at Bristol. I have already given a list of the earlier transits of the spot*, but the following three additional transits observed by Terby at Louvain † should be added to the list :—

Date.	Gr. m. t. of Transit.		
1885.	h	m	s
Mar. 19	7	50	18
„ 31	7	32	46
Apr. 19	8	11	42

A gradual change of colour seems to have occurred in the case of this spot. In 1887 it was always described as white or very white, usually the latter. In 1888 the spot is uniformly described as white previous to May 10, but from and after that date the colour has always been called "slightly yellowish."

Dark North Tropical Spot D.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 13	15 08	1	33·5	Rather S, D.	152
„ 20	15 57	4	35·8	Rather S, D, well def.	155
May 3	11 33	2	31·5	mL, D, well def.	166
„ 5	13 08	3	29·7	mL, well def.	169
„ 10	12 22	3	34·0	L, D, well def.	170
„ 12	13 58	3	32·8	mL, D, m well def.	173
„ 15	11 27	3	32·8	mL, D, well def, conspicuous.	177
„ 19	14 42·5	4	33·1	L, D, well def, conspicuous.	178
„ 20	10 32·5	3	31·8	L, D, well def, conspicuous.	179
„ 25	9 40·5	4	32·3	mL, vD, well def, v conspicuous.	184
„ 27	11 21	3	33·9	mL, D, well def.	186
June 1	10 25·5	4	32·3	mL, vD, v well def.	190
„ 3	11 59·5	2	29·8	mL, not vD, m well def.	192
„ 10	12 48·5	1	32·0	mL, D, m well def.	193
„ 13	10 19	2	32·6	mL, D, well def.	195
„ 30	9 25	3	35·2	mL, D, well def.	201
July 18	10 15±	..	40±	mL, mD, m well def.	208
Aug. 22	8 13	2	31·5	mL, mD, not v distinct.	210

* *Z. F.* vol. i. p. 23.
† See Terby's *Second Memoir* on Jupiter, pp. 35–37.

$R = 9^h\ 55^m\ 40^s{\cdot}9$ (316 rot.). The following are the residuals:—

Date.	O − C.	Date.	O − C.
1888.	m	1888.	m
Apr. 13	+1·9	May 25	−0·4
„ 20	+5·7	„ 27	+0·2
May 3	−1·6	June 1	−0·6
„ 5	−4·5	„ 3	−4·7
„ 10	+2·4	„ 10	−1·2
„ 12	+0·5	„ 13	−0·1
„ 15	+0·3	„ 30	+4·0
„ 19	+0·9	Aug. 22	−2·6
„ 20	−1·3		

the mean error of an observation being $\pm 2^m{\cdot}1$. This was a conspicuous and comparatively a well-defined spot, which projected considerably north of the NEB into the N. Tropical zone. From its position just following the conspicuous spot C, this spot D is evidently identical with the spot of the same name observed in 1887 *, but it had become a much more prominent object. Its motion, like that of C, had also become slower.

White North Tropical Spot D_2.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 20	16 17±	..	48±	B, m well def, not vL.	155
„ 26	11 05	2	41·8	B, m def.	156
May 3	11 51	3	42·4	Rather S, mB, m well def.	166
„ 5	13 30·5	2	43·3	Rather S, mB, m well def.	169
„ 10	12 47	2	49·1	mL, B, m well def.	170
„ 13	10 08	2	44·2	Rather S, B, well def, nearly R.	174
„ 15	11 57	2	50·9	mL, B, m well def.	177
„ 20	10 57	1	46·6	S, F, not well def.	179
„ 25	10 04	3	46·5	Rather S, B, m well def.	184
„ 27	11 40	2	45·4	Rather S, mB, not well def.	186
June 1	10 48·5	4	46·2	S, B, m well def, rather wh.	190
„ 3	12 30	3	48·2	S, B, m well def.	192
July 19	10 33	1	50·9	mL, mB, m well def, wh.	208
Aug. 22	8 32	1	43·0	mL, mB, m well def, wh.	210

* *Z. F.* vol. i. p. 24.

R = $9^h\ 55^m\ 41^s{\cdot}7$ (285 rot.). The residuals are :—

Date.	O−C.	Date.	O−C.
1888.	m	1888.	m
Apr. 26	−5·6	May 25	+1·1
May 3	−4·9	,, 27	−0·9
,, 5	−3·4	June 1	+0·1
,, 10	+5·9	,, 3	+3·4
,, 13	−2·3	July 19	+5·8
,, 15	+8·7	Aug. 22	−8·6
,, 20	+1·3		

The mean error of an observation is here large, being $\pm 3^m{\cdot}6$, but the spot was not very conspicuous nor very definite. There is no doubt as to its being identical with the spot of the same name observed in 1887 *, as it occupies nearly the same position relative to C and D that it did in the last-mentioned year. Moreover, the computed position of the spot of 1887 on the 26th April, 1888, is 46°, which differs by only 4° from the observed longitude on that date. But, like the preceding spots C and D, its motion received a check, the rotation-period in 1887 having been $9^h\ 55^m\ 34^s{\cdot}1$, or $7^s{\cdot}6$ shorter than it was in 1888.

White North Tropical Spot F.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 1	10 43	2	60·4	Rather S, rather F, badly def.	161
,, 15	12 22	1	66·0	S, F, inconspicuous.	177
,, 20	11 28	2	65·3	S, not B, badly def.	179
,, 30	9 36	2	61·6	Rather S, B, not well def.	187
June 1	11 18	3	64·0	S, nearly R, B, m well def.	190
,, 3	12 59·5	1	66·1	mL, mB, def confused.	192
,, 11	9 38·5	1	67·5	S, F, not well def.	194
,, 30	10 22	1	69·7	S, vF, ill def.	201

R = $9^h\ 55^m\ 47^s{\cdot}0$ (145 rot.). Usually a faint and inconspicuous spot, which is probably identical with the spot of the same name observed in 1887 †, though the identity cannot be regarded as certain.

* *Z. F.* vol. i. p. 24.
† *Ibid.* p. 25.

Dark North Tropical Spot G.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 1	16 40	1	104·6	A dark projection n of belt.	139
Apr. 4	14 07	2	83·2	m plain, D, projection.	145
,, 26	12 22	1	88·3	Not D nor well def.	156
May 1	11 21	2	83·4	mL, not def.	161
,, 3	13 07	3	88·3	mL, not vD, an ill-def bulge.	166
,, 5	14 31	2	79·9	Rather L, mD, m well def.	169
,, 13	11 22	1	88·9	mL, D, well def.	174
,, 15	12 59	1	88·4	mL, D, well def.	177
,, 20	11 58	2	83·5	Rather L, D, not well def.	179
,, 25	11 05	2	83·4	mL, D, m well def.	184
June 1	11 42	2	78·5	mL, mD, m well def.	190
,, 11	10 05·5	2	83·8	mL, mD, m well def.	194
,, 16	9 11	1	82·5	mL, mD, m well def.	197
,, 30	10 50	1	86·6	mL, mD, m well def.	201

R=$9^h\ 55^m\ 39^s{\cdot}1$ (210 rot.). A moderately plain spot, possibly identical with the spot of the same name observed in 1887 *. The first observation of March 1 is very discordant, but it is interesting, since it tends to indicate that the check in the motion of the spot, assuming it to be really identical with that observed in 1887, only occurred subsequently to the date of this observation, and probably about the end of March. On April 4 the spot was noted as being more conspicuous half an hour before it was in mid-transit than it was at the time of that event.

White North Tropical Spot H.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 4	14 33	3	98·9	mL, B, wh.	145
,, 6	16 15	3	101·4	L, B, well def.	148
,, 26	12 48	4	104·0	L, vB, v wh, well def.	156
May 1	11 55	2	104·0	Rather S, B, m well def.	161
,, 3	13 31	3	102·8	Rather S, rather F, not well def.	166
,, 5	15 12	3	104·7	mL, B, well def.	169
,, 10	14 20	3	105·3	mL, vB, well def.	170
,, 11	10 13	4	106·4	L, vB, a nearly R nucleus of greater brightness.	171
,, 15	13 29	3	106·5	mL, B, well def.	177
,, 20	12 35	3	105·8	mL, B, rather well def, wh.	179
,, 23	10 03	3	105·2	mL, B, well def.	182
,, 25	11 33	4	100·3	mL, vB, well def.	184
June 16	9 43	1	101·8	Rather S, mB, ill def.	197
Aug. 25	7 40·5	2	102·2	mL, B, m well def, except E & W.	212

* *Z. F.* vol. i. p. 27.

R=9^h 55^m 40^s·8 (345 rot.). The following are the residuals:—

Date.	O−C.	Date.	O−C.
1888.	m	1888.	m
Apr. 4	−7·2	May 11	+4·8
„ 6	−3·2	„ 15	+4·9
„ 26	+1·0	„ 20	+3·8
May 1	+0·9	„ 23	+2·7
„ 3	−1·1	„ 25	−5·3
„ 5	+2·0	June 16	−3·2
„ 10	+3·0	Aug. 25	−2·9

The mean error of an observation is ± 3^m·3, but it is evident from the residuals that the motion of the spot was not uniform, and that a much better agreement could be obtained by the adoption of a rotation-period changing slightly with the time. The spot was a rather conspicuous one, and it is probably identical with the spot of the same name observed in 1887 *, though, as in the case of the previous spots, with a change in its period of rotation.

Dark North Tropical Spot Q.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 4	15 14	2	123·7	Rather S, not vD.	145
May 3	13 54	2	116·7	L, not vD, not well def.	166
„ 10	14 40	2	117·4	mL, D, m well def.	170
„ 11	10 32	3	117·9	mL, D, m well def.	171
„ 15	13 49	2	118·6	mL, D, well def.	177
„ 20	12 54	2	117·3	Rather S, D, m well def, projecting acutely n of belt.	179
„ 23	10 28	3	120·3	mL, D, well def, projecting rather acutely.	182

R=9^h 55^m 34^s·4 (118 rot.). An inconspicuous spot.

* *Z. F.* vol. i. p. 29.

White North Tropical Spot R.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 4	15 31	2	134·0	Rather S, F, not well def.	145
„ 29	11 05·7	2	133·3	mB, much cloud.	157
May 1	12 46	1	134·8	mB, but shadow of I. hinders.	161
„ 3	14 17	2	130·6	mL, mB, m well def.	166
„ 11	10 52	3	130·0	Rather S, not vB, not well def.	171
„ 20	13 14	1	129·4	mL, B, well def, conspicuous.	179
„ 23	10 47	1	131·8	S, mB, m well def.	182

R=9^h 55^m $36^s·8$ (118 rot.).

White North Tropical Spot S.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 4	16 24	2	166·0	mL, B, m well def.	145
„ 26	14 33	1	167·5	mL, B, well def.	156
„ 29	12 03·7	2	168·4	mB, m well def.	158
June 14	9 47	2	163·6	mL, mB, not v well def.	196

R=9^h 55^m $37^s·7$ (171 rot.). This spot, together with the next spot T, may be identical with the spot K of 1887 *, this latter having been a very much elongated spot, or perhaps it should be better described as a short streak rather than a spot.

White North Tropical Spot T.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 11	12 15	1	180·1	mL, B, m well def.	171
„ 21	10 29·5	?	180·4	mL, vB, well def, v conspicuous.	180
„ 23	12 10	2	181·9	mL, B, m well def.	182

R=9^h 55^m $44^s·4$ (29 rot.). As already mentioned, this spot together with the preceding spot S may be identical with the long spot K of 1887.

* *Z. F.* vol. i. p. 31.

Dark North Tropical Spot K_2.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 11	12 39	3	194·6	mL, vD, well def.	171
„ 21	10 50	est	192·8	mL, mD, not v well def.	180
„ 23	12 25	..	191·0	mL, D, well def, rough obs.	182
June 2	10 50	3	197·5	mL, D, m well def.	191
„ 14	10 43	2	197·5	mL, mD, m well def.	196
Aug. 23	8 38	1	196·8	S, F.	211

R=9^h 55^m 40^s·7 (251 rot.). This spot is probably identical with the spot of the same name observed in 1887 *.

White North Tropical Spot U.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 21	16 36	est	228·4	Rather S, B, well def, v wh, indenting belt.	140
Apr. 5	13 53	2	225·2	mL, vB, well def.	146
May 1	14 40	4	203·7	mL, vB, well def, conspicuous.	162
„ 11	13 03·5	3	209·4	mL, B, not well def.	172
„ 26	10 22	1	207·9	mL, B, not well def.	185
June 2	11 15	2	212·6	mL, B, m well def.	191
„ 14	11 07	1	212·0	mL, B, m well def.	196
July 6	9 26·5	2	217·7	S, mB, not well def.	203

R=9^h 55^m 42^s·5 (258 rot.). The first two observations differ widely from the later ones, but they pretty certainly refer to the same spot, which was rather indefinite, although bright and conspicuous.

* *Z. F.* vol. i. p. 32.

Dark North Tropical Spot W.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 21	16 56	2	240·5	mD, m well def.	140
Apr. 5	14 15	3	238·5	L, mD, m well def, projecting n.	146
May 1	[15 05]	3	[218·8]	L, vD, v well def, v prominent.	162
„ 11	13 40	2	231·5	mL, mD, m well def.	172
„ 26	11 03	1	232·7	Rather S, F, poorly def.	185
June 2	11 51	2	234·3	mL, rather F, not v def.	191
„ 14	11 40	2	231·9	mL, mD, m well def.	196
July 6	10 00	3	238·0	mL, D, well def.	203
„ 18	9 37	est	226·9	mL, mD, m well def.	207

R=9^h 55^m $38^s·0$ (287 rot.).

White North Tropical Spot Y.

This spot was seen and drawn on May 14 and 21 and July 18, but the transit was only observed on May 21, namely at 12^h 15^m, wt.=1, Long.=244°·2.

White North Tropical Spot L.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 20	12 29	4	270·1	L, eB, m well def, wh.	153
„ 29	14 57·7	2	273·6	vL, vB, not v well def.	159
„ 30	10 45	1	271·3	Apparently B, but much cloud.	160
May 21	12 52	2	266·6	mL, B, m well def.	181
„ 24	10 17	3	264·0	mL, B, well def, wh.	183
„ 31	11 15	2	271·8	Rather L, mB, ill def.	188
June 17	10 05	2	265·5	Rather S, mB, m well def.	199
„ 22	9 13	3	265·7	mL, B, m well def.	200
July 6	10 40	1	262·1	mL, mB, m well def, wh.	203
„ 23	9 39	3	259·1	mL, B, well def, v wh, nearly R.	209

R=9^h 55^m $35^s·3$ (227 rot.). The residuals are :—

Date.	O−C.	Date.	O−C.
1888.	m	1888.	m
Apr. 20	−3·7	May 31	+7·8
„ 29	+3·9	June 17	+1·1
„ 30	+0·3	„ 22	+2·0
May 21	−3·0	July 6	−0·4
„ 24	−6·6	„ 23	−1·8

the mean error of an observation being $\pm 3^{m}\cdot 1$. This spot is undoubtedly identical with the spot of the same name observed in 1887 *, although the position does not accord exactly. Thus, we find the spot on April 20, 1888, in nearly the same longitude that it was in at the end of June 1887, although using the rotation-period derived from the observations of that year it should have been some 15° preceding that position. Again, calculating backwards with the period derived from the present series of observations, we get a position considerably following the observed place of L in 1887. These differences are probably due to real slight variations in the motion of the spot, for it will be noticed that there are indications of such variations in the observations of 1888. The great brilliancy, however, of the spot in 1887, and again in the early part of 1888, seems to render the identification certain. Moreover there is no other spot observed in 1888 that could well be identified with the spot L of 1887. Although the spot was a very prominent one in April 1888, yet it became distinctly less conspicuous later on. It was characterised by a very white aspect, as indeed it had been in the previous year.

Dark North Tropical Spot Z.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
June 22	9 40	2	282·0	Rather S, mD, m well def.	200
Aug. 31	7 53	1	290·4	mL, vD, well def.	213

In addition to the above two observations the spot was seen and drawn on May 21 and June 17.

White North Tropical Spot A_2.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 2	12 48	2	286·4	Rather S, B, well def, nearly R.	165
„ 4	14 24	1	285·2	mL, B, m well def, wh.	168
„ 12	10 58·5	3	284·3	mL, B, m well def, conspicuous.	173
„ 14	12 37	3	284·6	mL, mB, not well def, ragged on edges.	176
„ 21	13 26	2	287·1	Rather S, B, well def.	181
„ 24	10 50	3	284·0	Rather S, B, m well def.	183
„ 31	11 32	2	282·1	Not L, B, m well def.	188
June 10	10 05·5	3	293·5	S, mB, m well def, nearly R.	193
„ 17	10 56	1	296·4	Rather S, mB, m well def.	199
„ 22	10 06	3	297·7	mL, mB, m well def.	200
July 16	9 43·3	2	290·3	mL, vB, well def, v wh, nearly R.	206
„ 23	10 38	2	294·8	mL, mB, m well def.	209

* *Z. F.* vol. i. p. 32.

R=9^h 55^m 44^s·9 (198 rot.). The observations of this spot are very discordant. This would seem to be due to real changes in position or appearance of the spot, perhaps to both. There can hardly be any mistake in identification. But see the notes to the next spot.

Dark North Tropical Spot B_2.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 20	13 02	2	290·1	Ill def darkening and thickening of the belt.	154
,, 29	15 24·7	3	289·9	S, mD, not well def.	159
May 21	13 42	3	296·8	mL, vD, m well def.	181
,, 24	11 03	3	291·8	mL, D, well def.	183
,, 31	11 53	2	294·8	mL, mD, not well def.	188

R=9^h 55^m 47^s·0 (99 rot.). The observations of the three spots Z, A_2, and B_2 are so entangled that it is difficult to be quite certain on the subject of identification. It has therefore been thought best not to use the rotation-periods found for the last two spots in forming the mean period for the North Tropical spots. However, it seems probable that the identifications are correct, though there were evidently some changes going on in this region of the planet. The widening of the distance between the two white spots L and A_2 after May 31, with the subsequent appearance of an apparently new dark spot, Z, in between, recalls a feature very commonly occurring with the equatorial spots. On the other hand, it is not impossible that the dark spot Z may have been really identical with B_2, or at any rate that the observation of Aug. 31 refers to the latter spot.

White North Tropical Spot P.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 3	15 00	1	325·0	Rather S, B, well def, v wh.	144
,, 6	12 29	2	324·8	mL, B.	147
,, 13	13 17	2	326·4	mL, mB, m well def.	151
,, 20	14 05	2	328·2	mL, B, well def.	155
May 2	14 10	1	336·0	mL, mB, m well def.	165
,, 10	10 35	2	329·3	mL, B, m well def.	170
,, 12	12 10	2	327·5	Not vL, B, well def.	173
,, 14	13 52	3	330·0	mL, B, m well def.	176
,, 21	14 36	1	329·4	mL, B, well def.	181
,, 24	12 10	1	332·3	mL, B, well def.	183
June 10	11 11·5	3	333·4	Rather S, vB, nearly R.	193
,, 22	10 59	2	329·7	mL, B, m well def.	200
July 16	10 52	1	331·8	mL, B, m well def.	206

R = $9^h\ 55^m\ 43^s{\cdot}6$ (251 rot.). The residuals are :—

Date.	O−C.	Date.	O−C.
1888.	m	1888.	m
Apr. 3	− 1·7	May 14	+1·6
„ 6	− 2·3	„ 21	−0·1
„ 13	− 0·5	„ 24	+4·4
„ 20	+ 1·6	June 10	+4·0
May 2	[+12·9]	„ 22	−3·6
„ 10	+ 1·0	July 16	−2·8
„ 12	− 2·1		

the mean error of an observation being $\pm 2^m{\cdot}2$, omitting that of May 2. This spot is undoubtedly identical with the one of the same name observed in 1887 *. Only two transit observations were obtained in 1887, and these make the longitude in April and May of that year 331°·5 ; and this is practically what it was in 1888, though calculating backwards to 1887 with the period of 1888 we get a position somewhat preceding that observed. The motion of the spot in 1888 was evidently, however, not perfectly uniform, as the residuals indicate that the observations would be better satisfied by a rotation-period decreasing slightly in length with the time, so that too much stress must not be placed upon this circumstance, and there is no other white spot near, observed in 1887, that could be well identified with it, excepting, perhaps, spot A, when it would be necessary, however, to assume an analogous change but of even greater amount.

Dark North Tropical Spot C_2.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
June 1	9 34	2	361·1	mL, F.	190
„ 13	9 15	1	353·9	L, slight bulge and darkening of the belt, v indefinite.	195

Nothing definite can be concluded from these two apparently not accordant observations.

* *Z. F.* vol. i. p. 37.

Summary of North Tropical Spots.

Spot.	Rot.-Per.	No. of Rot.	No. of Obs.
	h m s		
White Spot C	9 55 38·8	362	22
Dark Spot D	9 55 40 9	316	17
White Spot D_2	9 55 41·7	285	13
White Spot F	9 55 47·0	145	8
Dark Spot G	9 55 39·1	210	14
White Spot H	9 55 40·8	345	14
Dark Spot Q	9 55 34·4	118	7
White Spot R	9 55 36·8	118	7
White Spot S	9 55 37·7	171	4
White Spot T	9 55 44·4	29	3
Dark Spot K_2	9 55 40·7	251	6
White Spot U	9 55 42·5	258	8
Dark Spot W	9 55 38·0	287	9
White Spot Y	.....	..	1
White Spot L	9 55 35·3	227	10
Dark Spot Z	.....	..	2
White Spot A_2	[9 55 44·9]	198	12
Dark Spot B_2	[9 55 47·0]	99	5
White Spot P	9 55 43·6	244	13
Dark Spot C_2	.....	..	2

Mean Rotation-Period of North Tropical Spots = $9^h\ 55^m\ 39^s{\cdot}92$ (15 spots).

Spots F, R, and S were given half weight in forming the above mean result; spot Q $\frac{3}{4}$ weight; and spot T $\frac{1}{4}$ weight.

(iii.) The North Equatorial Spots.

In 1887 a number of dark spots were visible on the south edge of the North Equatorial belt, but only five of them were sufficiently well observed to enable their periods of rotation to be derived. No distinct white spots were noticed in this year, although several were seen by Terby at Louvain, and are shown in the drawings of his *Third Memoir* on Jupiter. But in 1888 not only were many more of the dark projecting spots observed, but also many white spots; 27 spots altogether, both white and dark, being well enough observed to give satisfactory determinations of rotation-period.

Although some of the dark spots underwent considerable changes, yet their general aspect was very similar. That is they appeared as rather small, dark, sometimes almost black-looking projections extending in a south preceding direction into the bright Equatorial zone. In many cases, particularly in the earlier part of the apparition, fainter extensions of these projecting spots, in the form of dusky streaks or wisps, continued in a south preceding direction right across the Equatorial zone to dark spots on

the north side of the South Equatorial belt. Also, especially in the later part of the apparition, in many cases broader and darker streaks extended in a southerly direction across the Equatorial zone to other dark spots on the north edge of the South Equatorial belt. The general arrangement of the dark spots and wisps will be easily gathered from Plate I.

From observations made under more favourable conditions in later years we can now surmise that almost invariably just preceding these little dark projecting spots there was a bright rift or channel breaking into the dark material of the North Equatorial belt. Owing to the low altitude of Jupiter, and the consequently unfavourable circumstances, none of these bright rifts were actually observed distinctly in 1888, but several of them were detected by Terby in the previous apparition of 1887, and are represented in the drawings reproduced in his *Third Memoir*.

The white spots consisted of rather small and more or less irregular or indefinite, but often brilliant white spots on the south edge of the North Equatorial belt. Some of them, occupying a position just preceding the dark projecting spots, were probably connected more or less intimately with the bright rifts before alluded to. In some cases fainter white material appeared to extend in a southerly direction across the Equatorial zone, and to join these white spots to white South Equatorial spots. Several similar white streaks had been observed in the preceding year, although the white North Equatorial spots, as already mentioned, were not then noticed.

All the observations of the North Equatorial spots have been laid down on the Spot Chart forming Plate VII., to which reference should be made with respect to the general question of identification. This Chart will also show the accordance of the observations and the changes in position, or motion, of the individual spots. These last-mentioned changes were sometimes very considerable, but the observations are so numerous and so well distributed, that there cannot be any doubt, I think, as to the general correctness of the identifications. In the cases of the spots 23, 23 *a*, 24 and 24 *a*, there may, indeed, be a certain amount of doubt. Also it may be doubted perhaps whether the last observations attributed to spots 10 and 11 really relate to these spots. It is quite possible here that the old spots may have died out, and that the last observations refer to new spots, which had made their appearance in nearly though not quite the same longitudes. But what is perfectly certain is that an occasional mis-identification of this kind can have little or no practical influence on the accuracy of the final or mean result. For where there are so many as 20 or 30 spots, it is found in practice that a mis-identification in the case of one spot is almost invariably corrected or counterbalanced by a mis-identification in the opposite direction in the case of an adjoining spot, so that the final mean result is but little affected. Moreover, two or three partially incorrect results would have but little influence on a mean value derived from 20 or 30 spots. It may therefore be safely concluded that the mean rotation-period derived from the present series of observations does in fact represent the real average rotation-period of the surface material in this latitude or region of the planet.

The changes in the positions or motions of the North Equatorial spots do not always synchronise exactly with similar changes in the motions of the South Equatorial spots in corresponding longitudes of Jupiter, as will be seen by comparing Plates VII. and VIII. In particular the sudden and very

remarkable change which occurred in the motions of nearly all the South Equatorial spots in May does not seem to have directly affected the North Equatorial spots much, excepting between longitudes 110° and 170°. The remarkable changes in motion, size, and appearance of the dark North Equatorial spot 27 and the dark South Equatorial spot I. will be referred to under the latter spot. I have not attempted to identify any of the North Equatorial spots observed in 1888 with those seen in the previous year, on account of the considerable changes that evidently occurred.

The mean rotation-period of the five North Equatorial spots observed in 1887 was $9^h\ 55^m\ 40^s{\cdot}06$, which is nearly 18^s longer than that of the South Equatorial spots in the same year. The mean rotation-period from the 27 spots of 1888 is $9^h\ 55^m\ 23^s{\cdot}88$, which is slightly less than that derived from the South Equatorial spots.

It is very important to bear in mind that the longitudes in this subsection are invariably longitudes in System I. of Marth's Ephemeris.

White North Equatorial Spot 1.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 15	11 15	est	25·5	mL, mB, wh.	177
June 2	12 07	1	28·0	mL, B, wh.	191
„ 14	9 29	2	31·6	mL, not B.	196
„ 16	10 31	2	26·0	mL, mB, wh.	197
„ 30	9 10	3	32·6	Rather S, nearly R.	201
July 18	10 12	1	38·4	mL, mB, well def.	207

R=$9^h\ 50^m\ 24^s{\cdot}00$ (156 rot.). This was a moderately bright spot, joined to the white South Equatorial spot II. by a white streak. It was rather smaller than the latter spot.

Dark North Equatorial Spot 2.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 13	10 14	2	31·6	S, mD, D streak to III.	174
„ 20	9 33·5	1	35·5	S, F, D streak to III.	179
„ 24	11 57	2	36·6	vS, mD, streak to III. not seen.	183
June 14	9 38	3	37·1	S, D, streak to III. not seen.	196
„ 16	10 46	2	35·2	S, D, streak to III. not seen.	197
„ 30	9 28	3	43·6	S, mD, plain D streak to III.	201
July 18	10 32	1	50·6	S, rather F, F D streak to III.	207
Aug. 31	7 38	1	61·9	S, D, distinct D streak to III.	213

R=9h 50m 26s·72 (268 rot.). Excepting on May 24 and June 14 and 16, this spot was always seen joined to the dark South Equatorial spot III. by a dark streak. Notwithstanding slight shifts in the relative positions of the two spots, the streak is always delineated as running in a straight line from one spot to the other.

Dark North Equatorial Spot 3.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 3	16 13	1	35·6	Short streak s side of NEB, with F streak sp to III.	144
„ 6	13 08	3	37·8	S, mD, plain streak to III.	147
„ 13	12 37	2	47·4	Rather S, plain streak to III.	151
„ 29	12 22·7	2	52·7	Not vD, projecting sp.	158
May 1	13 48	3	61·5	vS, D, F streak to SEB f spot III.	162
„ 4	10 35	1	58·9	D streak sp to SEB.	..
„ 13	11 07	1	63·7	S projection with F streak to III.	174
„ 15	12 13	2	60·9	S projection with streak to III.	177
„ 19	14 39·5	3	63·8	S projection with streak sp to SEB.	178
„ 24	12 37	1	61·0	S projection, streak not obs.	183
„ 31	11 44	3	63·3	S, D projection, plain streak sp to III.	188
June 14	10 20	1	62·7	S, D projection, streak to III.	196

R=9h 50m 32s·86 (175 rot.). This was a rather interesting little spot, which projected in a sp. direction into the Equatorial zone. A dark streak or wisp was recorded in nearly every observation extending in a sp. direction to the South Equatorial belt. Generally this wisp appeared to run to the dark spot III., but on April 29 and May 1 it went to a point on the SEB following that spot, though subsequently it was again seen to run to III. It would seem from this as though the wisp emanated from spot 3 rather than from spot III., as the shifts in the relative positions of the two spots would in such case account for the observed changes. Spot 3 was also seen on June 16, though the transit was missed, but after this date it must have disappeared rather suddenly, for it was not seen again.

White North Equatorial Spot 4.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 31	11 54	2	69·4	mL, mB, v wh.	188
June 14	10 32	2	70·0	mL, B, wh.	196
„ 16	11 50	3	74·2	mL, B, wh.	198
„ 30	10 13	2	71·0	mL, B, wh.	201
July 16	9 51·3	3	69·4	mL, B, v wh.	206
„ 18	11 05	..	70·7	mL, vB, time v rough.	207
Aug. 31	7 57	1	73·5	mL, B, v wh.	213

R=$9^h\ 50^m\ 17^s{\cdot}65$ (224 rot.). A rather brilliant and definite white spot, which was always observed to be joined to the white spot IV. by a white streak.

White North Equatorial Spot 5.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 27	10 18	3	91·3	mL, B, v wh, well def.	186
„ 31	12 36	2	95·1	Not vL, not vB, wh.	189
June 14	11 16	2	96·8	mL, mB, wh, streak to VI.	196
„ 30	10 50	1	93·6	mL, B, wh, streak to VI.	201
July 16	10 25	1	89·9	mL, mB, wh, streak to VI.	206
„ 23	9 39	3	89·2	mL, B, v wh, streak to VI.	209
Aug. 22	8 00	2	92·6	mL, B, streak to VI.	210
„ 31	8 35	dup	96·7	mL, vB, R, wh streak to VI.	213

R=$9^h\ 50^m\ 16^s{\cdot}70$ (234 rot.). This white spot is particularly interesting from the fact of its having on May 27 occupied almost exactly the same position which the *dark* spot 6 had done only three days earlier. This is a remarkable and somewhat rare circumstance. On May 27 the dark spot was seen just following the white one, though its transit was not observed, so that it evidently experienced a similar shift of position to that of spot 5. But after this date the dark spot seems to have disappeared for a time, and it is doubtful whether the spot observed on July 16 is the same spot or a fresh one which made its appearance subsequently nearly in the same position. Because of this uncertainty, it has been thought advisable not to use this dark spot 6 for rotation-period purposes, though for convenience the observations are included below as though they related to one and the same spot.

Dark North Equatorial Spot 6.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 20	11 04	2	90·7	S, mD, wisp sp to V.	179
„ 24	13 25	1	90·3	S, mD, wisp sp.	183
July 16	10 32	2	94·2	S, mD.	206
Aug. 22	8 07	1	96·9	vS, vF, v difficult.	210

See the remarks to the preceding spot. It is probable, though not free from doubt, that all the observations in the table do relate to the same spot.

White North Equatorial Spot 7.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 20	11 26	3	104·2	mL, mB, streak to VI.	179
July 16	10 50	1	105·2	mL, mB, streak to VII.	206
„ 23	9 59	dup	101·4	mL, B, streak to VII.	209
Aug. 22	8 21	2	105·4	mL, mB, streak to VII.	210

R = $9^h\ 50^m\ 16^s{\cdot}45$ (229 rot.). Between May 20 and July 16 the spot seems to have either become very faint or else to have disappeared for a time, though the identification appears to be pretty certainly correct, notwithstanding the gap in the observations. At any rate, little difference would be produced in the adopted rotation-period by rejecting the first observation.

Dark North Equatorial Spot 8.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 15	13 14	2	116·4	mL, D, well-def projection, wisp to VIII.	177
„ 20	11 48	2	117·6	Rather S, D, wisp to VIII.	179
July 16	11 10	2	117·4	S, D projection, wisp to VIII.	206
„ 23	10 27	1	118·5	S, mD projection.	209
Aug. 22	8 45	1	120·1	Rather S, mD projection.	210

R=9^h 50^m 17^s·16 (241 rot.). There are no observations between May 20 and July 16, so that, like the adjacent spots, it must have become very feeble or else have disappeared altogether for a time. But here also but little difference would be caused to the adopted period of rotation by rejecting the first two observations.

White North Equatorial Spot 9.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 25	9 49	3	116·9	Not vL, mB, wh.	184
„ 27	10 57	2	115·1	mL, mB, wh.	186
June 3	10 21	dup	121·7	mL, B, wh.	192
„ 10	9 45·5	3	128·4	mL, B, wh.	193
„ 14	12 11	1	130·4	mL, mB, wh.	..
July 23	10 55	2	135·6	mL, B.	209
Aug. 22	9 12	est	136·5	mL, B, wh.	210

R=9^h 50^m 27^s·43 (217 rot.). A white streak southwards to spot IX. was recorded at every observation.

Dark North Equatorial Spot 10.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 25	10 19	2	135·1	Very minute, vF projection.	184
June 10	10 12·5	3	144·8	S, D.	193
„ 17	9 43	4	155·1	Rather S, D projection.	199
July 19	8 50	est	146·5	S, mD projection.	208

R=9^h 50^m 24^s·26 (134 rot.). Notwithstanding the irregular motion, and the large gap separating the last observation from the earlier ones, there can hardly be any doubt as to identification, because all the observations describe the spot as being connected with the dark spot X. by means of a dark streak. This streak ran in a south preceding direction from 10 at first, but at the last observation the direction was south a little following. The change of direction was due to the change in the relative positions of the two spots.

White North Equatorial Spot 11.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 20	12 25	2	140·1	mL, rather F, wh.	179
„ 25	10 38	3	146·7	mL, rather F, wh.	184
„ 27	12 00	1	153·5	mL, B, v wh.	186
June 1	10 00·5	3	152·5	mL, mB, wh.	190
„ 3	11 15	2	154·6	mL, mB, wh.	192
„ 10	10 38·5	3	160·7	mL, mB, wh.	193
„ 17	10 07	3	169·7	mL, B, wh, nearly R.	199
July 19	9 22	1	166·1	mL, B, nearly R.	208

R=9^h 50^m $31^s·71$ (146 rot.). In all the observations a white streak connected the spot with the white spot XI., so that there cannot be any doubt as regards the identification.

Dark North Equatorial Spot 12.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 23	10 16	2	176·5	S, mD projection.	182
„ 25	11 19	3	171·7	S, D projection.	184
June 3	11 51	2	176·5	S, D projection.	192
„ 10	11 03·5	3	175·9	Rather S, D projection.	193
„ 17	10 25	1	180·7	vS, D, difficult.	199

R=9^h 50^m $22^s·57$ (61 rot.). The spot was also seen on July 19 and Aug. 25, though the transits were not observed.

White North Equatorial Spot 13.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 11	13 07	4	180·3	mL, vB, v wh.	172
„ 13	14 13	1	177·1	L, B, wh.	175
„ 20	13 55	2	195·0	mL, B, wh.	179
„ 23	10 30	3	185·1	mL, B, wh.	182
„ 25	11 41	2	185·2	mL, rather F, wh.	184
June 3	12 03·5	3	184·2	mL, B, wh.	192
„ 10	11 22·5	2	187·5	mL, rather F, wh.	193
„ 17	10 43	2	191·7	mL, rather F, wh.	199
July 19	10 05	1	192·3	mL, vB.	208
Aug. 25	7 43·5	2	196·8	mL, B, wh.	212

R=9^h 50^m $20^s{\cdot}77$ (258 rot.). A rather bright and conspicuous spot, from which a white streak extended nearly due south to the SEB. It is noteworthy that prior to and up to May 25 this streak appeared to run to the white spot XV., but that on and after June 3 it went to the adjoining spot XIII. The change was due to the fact that spots XIII. and XV. were about this time moving with abnormal slowness, whilst spot 13 was, on the other hand, moving rapidly, so that the relative positions of the spots had changed in the interval. This is confirmatory of the view that certain of the white and dark streaks were emanations from the North Equatorial spots rather than from the South Equatorial spots. This view is, however, by no means to be regarded as established or universal, and some observations do not support it. More probably the wisps emanate sometimes from the North Equatorial spots and sometimes from the South Equatorial spots.

Dark North Equatorial Spot 14.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 20	14 14	2	206·6	S, D, well-def projection.	179
„ 23	11 05	2	206·4	vS, vD, nearly black projection.	182
June 10	11 37·5	1	196·7	S, mD projection.	193
Aug. 25	7 55·5	1	204·1	S, rather F, not easy.	212

R=9^h 50^m $14^s{\cdot}86$ (236 rot.). Here we have a similar peculiarity to that which occurred in the case of the preceding spot. On May 20 and 23 there was a dark wisp apparently connecting the spot to spot XVI., whilst on June 10 this wisp appeared to join it to spot XIV., instead of XVI. A similar explanation applies. The change was due to the abnormally slow motion of the South Equatorial spots, combined with the abnormally rapid motion of spot 14. Although the latter spot was not observed between June 10 and Aug. 25, there cannot be much doubt as to identification, because both spots 13 and 15 were observed in the interval. On account, however, of the slight uncertainty this result has been given only half weight.

White North Equatorial Spot 15.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 23	11 10	2	209·5	mL, mD, wh.	182
June 1	11 25	2	204·0	mL, rather F, wh.	190
„ 3	12 44	2	208·9	mL, mB, wh.	192
„ 10	11 55·5	2	207·7	mL, mB, wh.	193
„ 17	11 10	3	208·1	mL, B, wh, nearly R.	199
„ 22	9 14	3	208·8	mL, B, wh, nearly R.	200
July 1	9 46·5	1	213·1	mL, B.	202
„ 19	10 48	1	218·5	mL, mB, nearly R.	208
Aug. 25	8 20·5	2	219·4	mL, B, nearly R.	212

R = 9h 50m 21s·43 (229 rot.). A rather brilliant, well-defined white spot. On May 23 it was joined to the white spot XVII. by a white streak, but from and after June 1 this streak apparently connected it to spot XV. The explanation is the same as that given for spots 13 and 14. The identification of the South Equatorial spots seems to be quite certain, as is also that of the North Equatorial spots, so that there can hardly be any doubt as to the correctness of the foregoing explanation, which is also supported by the drawings so far as they go, though it is regrettable that the observations were not more numerous just at this critical time.

Dark North Equatorial Spot 16.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
June 1	11 40	2	213·1	S, D, well def.	190
„ 3	12 53	1	214·4	S, mD, inconspicuous.	192
„ 17	11 21	1	214·8	vS, D, v difficult.	199
„ 22	9 32	3	219·8	S, mD.	200

R = 9h 50m 28s·69 (51 rot.).

White North Equatorial Spot 17.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 23	[11 50]	2	[233·9]	mL, mB, wh.	182
June 1	[12 07]	1	[229·6]	Rather S, rather F.	190
„ 13	[9 25]	2	[230·8]	mL, F.	195
„ 17	11 33	3	222·2	mL, B, nearly R.	199
„ 22	9 49	3	230·2	mL, F.	200
July 1	10 19·5	1	233·2	mL, mB, nearly R.	202
Aug. 25	8 50·5	..	237·7	mL, mB, v rough.	212

R = 9h 50m 20s·61 (156 rot.). This is a rather interesting spot. On May 23 a white streak was noted extending southwards to the white spot XVIII. On June 1 and June 13 this streak is shown joining spot 17 to spot XVII., instead of XVIII., which latter was not seen on either of these two nights. Spot 17 seems to have then split into two *, one component being joined to XVII. by a white streak, and the other to XVIII. by a similar streak. Between the two a dark spot, 18, made its appearance (see Plate VII.). For the purpose of computing the rotation-periods of spots 17 and 19 I have used only the observations subsequent to the division into two spots; and the two results have been given half-weight.

* Or as an alternative it may perhaps be better stated that the dark spot, 18, then made its appearance, dividing the formerly existing white spot into two.

Dark North Equatorial Spot 18.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
June 22	10 07	2	241·1	S, mD, no wisp.	200
July 1	10 38·5	2	244·8	S, mD, wisp s susp.	202
Aug. 23	7 51	..	245·2	S, D, well def, plain wisp. Time the mean of an est transit and a double transit.	211

R = 9^h 50^m $18^s{\cdot}50$ (151 rot.). This is the dark spot referred to in the remarks on the preceding spot. It is interesting to note that a new dark spot also came into existence between the spots XVII. and XVIII.; and that on Aug. 25 a dark wisp was seen joining it to the present one.

White North Equatorial Spot 19.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 23	[11 50]	2	[233·9]	mL, mB.	182
June 1	[12 07]	1	[229·6]	Rather S, rather F.	190
„ 13	[9 25]	2	[230·8]	mL, F.	195
„ 17	12 07	2	242·9	mL, B, wh.	199
„ 22	10 19	3	248·4	mL, B, nearly R, wh.	200
July 1	10 52·5	1	253·3	mL, mB.	202
„ 6	8 55·5	dup	253·2	mL, rather F.	203
Aug. 23	8 13	4	258·6	mL, eB, a well-def disc.	211

R = 9^h 50^m $22^s{\cdot}47$ (151 rot.). The first three observations relate to the single spot, which later on divided into two, as already described under spot 17. At the last observation the spot was a very brilliant disc-like object.

Dark North Equatorial Spot 20.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 2	14 37·5	2	250·0	Rather S, a not vD projection.	165
„ 11	14 58	2	248·0	mL, D projection.	172
„ 12	10 34·5	2	245·7	Rather S, D projection.	173
„ 14	11 49	3	247·9	S, rather F projection.	176
„ 23	12 20	1	252·2	No description, seeing bad.	182
Aug. 23	8 38	1	273·8	S, D projection.	211

R=9h 50m 25s·76 (275 rot.). In May this was a rather conspicuous projection, with a dark wisp to spot XIX., and another wisp sp to spot XVI., but after May 23 it either became very faint or else disappeared altogether. On June 22 it could not be seen, although it was specially looked for. Owing to this circumstance the foregoing result has been given half-weight, though there can be little doubt but that the observation of Aug. 23 either refers to the same spot or else to a new one which made its appearance in practically the same place.

White North Equatorial Spot 21.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 2	14 55	4	260·7	mL, vB, v wh, oval.	165
„ 10	9 38±	..	254·4±	mL, vB, v wh.	170
„ 14	12 22	3	268·0	Rather S, B, wh, oval.	176
„ 23	12 52	1	271·7	mL, B, wh.	182
June 11	9 22·5	3	272·7	mL, B, v wh.	194
„ 17	12 58	1	274·0	mL, B, wh.	199
„ 22	10 59	2	272·9	mL, B, wh, nearly R.	200
July 6	9 35·5	2	277·6	mL, mB.	203
Aug. 23	9 12·5	..	294·9	mL, mB, wh, nearly R. Time the mean of an est and a double transit.	211

R=9h 50m 28s·12 (275 rot.). A bright and conspicuous spot. It was usually joined to the white spot XX. by a white streak. On May 2, however, this streak ran, not to spot XX., but to the South Equatorial belt just preceding that spot. This is a further confirmation of the view that the white streaks, in some cases at least, emanated from the North Equatorial spots rather than from the South Equatorial spots.

Dark North Equatorial Spot 22.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 3	13 01	1	278·5	Not L, mD, sp end of a short streak.	144
„ 26	11 55	2	280·6	Rather F projection.	156
May 10	10 20	3	280·1	S, D projection.	170
„ 12	11 29	3	278·9	Rather S, D projection.	173
„ 14	12 38	3	271·7	S, D projection.	176
June 11	9 40·5	3	283·6	S, mD projection.	194
„ 22	11 20	1	285·7	S, mD projection.	200
July 6	9 53·5	2	288·6	vS, mD projection.	203

R=9^h 50^m 19^s·90 (229 rot.). A curious dark projection with two wisps, one running in a sp direction to spot XIX., and the other in a southerly direction to spot XXI.

White North Equatorial Spot 23.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 3	13 28	2	294·9	mL, B, v wh.	144
„ 26	12 20	1	295·9	End of a F streak.	156
May 3	11 54	4	308·7	L, B, wh, nearly R.	166
„ 12	12 10	2	303·9	mL, B, nearly R.	173
„ 14	13 13	3	299·1	mL, B, wh.	176
„ 21	12 37	3	305·8	mL, B, v wh.	181
„ 26	10 45	2	309·4	mL, B, v wh.	185
June 2	9 55	2	307·4	mL, B, wh.	191
„ 11	10 37	est	318·1	mL, mB.	194
July 6	10 58	3	327·9	mL, B, wh.	203

R=9^h 50^m 30^s·05 (229 rot.). The observations of the spots in this longitude strongly point to the uncommon fact of two white and dark spots in the same latitude passing one another. Either this must have been what happened, or else great changes must have occurred in this region of the planet. The former is perhaps the more probable. To give all the evidence in favour of this would require considerable space and the reproduction of the drawings, but the probable course of the change that resulted will be seen from Plate VII. The dark spot 24 apparently divided into two spots after May 12, and between May 24 and May 26 the preceding component, called 24 *a*, seems to have crossed from the following to the preceding side of the white spot 23. Subsequently also a white spot, 23 *a*, made its appearance preceding 24 *a*, though it is possible that this should rather be regarded as an offshoot from spot 23.

White North Equatorial Spot 23 *a*.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
June 11	10 06·5	2	299·5	mL, mB, wh.	194
July 6	10 18	2	303·5	Rather S, mB, nearly R.	203

See notes to the last spot. As there are only two observations, separated by a time interval of less than a month, it has not been thought worth while to use this spot for rotation-period purposes.

Dark North Equatorial Spot 24 *a*.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 14	13 26	3	307·1	S, mD projection.	176
„ 24	9 28	2	305·7	S, vD, blackish projection.	183
„ 26	10 34	1	302·7	S, D projection.	185
June 2	9 47	1	302·6	S, D projection.	191
„ 11	10 16	2	305·3	S, mD projection.	194
July 6	10 37	3	315·1	Rather S, D projection.	203

R=$9^h\ 50^m\ 23^s{\cdot}38$ (129 rot.). See note to spot 23.

Dark North Equatorial Spot 24.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 5	15 00	1	307·7	Short D projection.	146
May 1	11 02	2	320·2	Rather S, mD projection.	161
„ 3	12 07	3	316·6	S, F projection.	166
„ 5	13 14	3	314·2	S, mD projection.	169
„ 10	11 18	3	315·4	Rather S, mD projection.	170
„ 12	12 21	3	310·6	Rather S, mD projection.	173
„ 14	13 40	2	315·6	S, F projection.	176
„ 21	12 50·5	2	314·1	S, mD projection.	181
„ 24	....	..	....	Seen and drawn.	183
„ 26	....	..	....	S, mD projection.	185
June 2	10 16	3	320·2	S, D projection.	191
July 6	11 17	3	339·5	Rather S, D projection. Time by dup transit=$11^h\ 20^m{\cdot}7$.	203

R=$9^h\ 50^m\ 29^s{\cdot}84$ (224 rot.). As already mentioned under spot 23, this spot 24 divided into two after May 12, or perhaps it would be better to describe spot 24 *a* as being an offshoot from spot 24.

White North Equatorial Spot 25.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 14	14 15	3	336·9	Rather S, B, wh.	176
„ 21	13 30	2	338·2	mL, mB, v wh.	181
„ 24	10 24	3	339·7	mL, B, v wh.	183
„ 26	11 29	3	336·2	mL, vB, wh.	185
June 2	10 52	3	342·2	mL, B, wh.	191
„ 16	9 22	2	343·9	Rather S, F, wh.	197
July 18	9 02	2	355·7	mL, B.	207

R = 9^h 50^m $27^s{\cdot}54$ (158 rot.). A conspicuous white spot, which on May 14 and 21 was joined to spot XXV. by a white streak, but in all the subsequent observations this streak is drawn as extending to spot XXIV., and not to XXV. It is probable that the next spot, 26, was an offshoot from 25, and that on its formation or separation the white streak from 25 ran to XXIV., instead of to XXV. Later on another white streak connected 26 with XXV.

White North Equatorial Spot 26.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
June 2	11 04	2	349·5	S, rather F, v wh.	191
„ 16	9 35·3	4	352·0	mL, B, wh.	197
July 6	11 42±	..	354·8±	mL, B.	203
„ 18	9 12	2	1·8	mL, B.	207

R = 9^h 50^m $26^s{\cdot}70$ (112 rot.). See note to spot 25.

Dark North Equatorial Spot 27.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 1	13 32	2	338·0	Rather S, D.	143
„ 3	14 42	2	340·1	Rather S, inconspicuous.	144
„ 8	12 50	2	343·5	vL, vD projection.	150
„ 26	13 55	4	353·8	mL, not vD. Time by dup transit = 13^h 55^m.	156
May 1	12 06·5	3	359·5	Rather S, not D.	161
„ 3	13 10	3	355·0	vF, v difficult.	166
„ 5	14 26	2	358·1	S, F.	169
„ 10	12 30	3	359·3	S, F.	170
„ 12	13 55	1	355·7	S, F projection.	173
„ 21	13 56	2	354·0	Rather S, mD.	181
„ 24	10 45	3	352·6	Rather S, mD.	183
June 2	11 10	3	353·2	S, D, blackish projection.	191
„ 16	9 50	3	1·0	S, mD projection.	197
July 18	9 50	2	12·8	S, mD projection.	207

R = 9^h 50^m $27^s{\cdot}99$ (263 rot.). The remarkable changes which this spot underwent are referred to more particularly under the South Equatorial Spot I.

Spots 10, 11, 12, 14, 16, 17, 18, 20, and 26 were given half-weight in forming the undermentioned mean rotation-period of the North Equatorial spots.

Summary of North Equatorial Spots.

Spot.	Rot.-Per.	No. of Rot.	No. of Obs.
	h m s		
White Spot 1	9 50 24·00	156	6
Dark Spot 2	9 50 26·72	268	8
Dark Spot 3	9 50 32·86	175	12
White Spot 4	9 50 17·65	224	7
White Spot 5	9 50 16·70	234	8
Dark Spot 6	....	..	4
White Spot 7	9 50 16·43	229	4
Dark Spot 8	9 50 17·16	241	5
White Spot 9	9 50 27·43	217	7
Dark Spot 10	9 50 24·26	134	4
White Spot 11	9 50 31·71	146	8
Dark Spot 12	9 50 22·57	61	5
White Spot 13	9 50 20·77	258	10
Dark Spot 14	9 50 14·86	236	4
White Spot 15	9 50 21·43	229	9
Dark Spot 16	9 50 28·69	51	4
White Spot 17	9 50 20·61	156	7
Dark Spot 18	9 50 18·50	151	3
White Spot 19	9 50 22·47	151	8
Dark Spot 20	9 50 25·76	275	6
White Spot 21	9 50 28·12	275	9
Dark Spot 22	9 50 19·90	229	8
White Spot 23	9 50 30·05	229	10
White Spot 23 *a*	....	..	2
Dark Spot 24 *a*	9 50 23·38	129	6
Dark Spot 24	9 50 29·84	224	10
White Spot 25	9 50 27·54	158	7
White Spot 26	9 50 26·70	112	4
Dark Spot 27	9 50 27·99	263	14

Mean Rotation-Period of North Equatorial Spots
$=9^h\ 50^m\ 23^s{\cdot}88$ (27 spots).

(iv.) The South Equatorial Spots.

The general appearance of the South Equatorial spots in 1888 was very similar to what it had been in 1887. As in the latter year, there were numerous irregular, dark masses or spots on the northernmost component of the coarsely double South Equatorial belt, most of them projecting to a greater or less extent into the bright Equatorial zone. Between these dark spots were brilliant white areas or spots, which usually appeared to indent or encroach upon the dark South Equatorial belt. In the light of our present knowledge we know that in many cases comparatively narrow but brilliant channels or rifts, starting from these spots, penetrated into and

frequently right through the northernmost component of the South Equatorial belt; but none of these were distinctly seen in 1888, doubtless chiefly on account of the unfavourable position of Jupiter. In a good many cases there are records of bright spots being seen in the central rift of the South Equatorial belt, like that shown above spot IX. in Plate I., but none of these was observed sufficiently well to enable its rotation-period to be ascertained with certainty *.

In one important detail, however, there is a difference compared with 1887. In that year many dark spots were observed on the southernmost component of the South Equatorial belt, as well as on the northernmost component; and it would seem from the observations of these spots † that they partook of the rapid motion of the spots on the northernmost component of the belt. Or in other words this would imply that in 1887 the great Equatorial current of Jupiter extended so far south as to include or cover the southernmost component of the South Equatorial belt, or at any rate the northern portion of it. But in 1888 only a very few dark spots were observed on the southernmost component of the belt, and it appears probable that in this year the Equatorial current did not extend appreciably south of the great central rift of the belt.

Again, as in 1887, the region of the South Equatorial spots proved to be by far the most disturbed of any region of the planet, all the spots, both light and dark, being more or less in a constant state of change: and the changes, moreover, being often very great and very sudden. The changes of the dark spot I., in conjunction with those of the North Equatorial spot 27, were particularly great and interesting, as will be seen from the figures of Plate III. The apparent connection of the dark South Equatorial spots with dark North Equatorial spots by means of dark streaks or wisps has already been referred to in the general remarks on the North Equatorial spots, as has likewise the gradual change in the direction and general aspect of these wisps.

All the observations for longitude of the South Equatorial spots have been inserted in the chart, Plate VIII., which shows clearly the remarkable changes which occurred in the motions of the different spots. The general question of the correctness, or otherwise, of the identification of the different spots will also be evident from an inspection of this Plate. Although in a few instances an alternative identification of the observations is perhaps possible, yet on the whole I feel quite satisfied as to the correctness of the identification, because the observations are in most cases sufficiently numerous and so distributed as to prevent possibility of doubt; whilst by the system of identification here adopted every observation is satisfactorily accounted for, which would not be the case if any alternative system of identification were adopted.

Coming now to the details of the motions of the spots, we have to notice firstly the very remarkable change that occurred about the middle of the month of May. At this time the motions of the spots nearly all round the planet received a rather sudden check, by which their rotation-periods

* The one in the rift opposite to spot II. should be perhaps excepted. See the figures of Plate III.

† See, for example, those of spot XII. of that year (*Z. F.* vol. i. p. 78).

increased much in length. This remarkable change is particularly evident between longitudes 0° and 230° (of System I., not System II.). And what seems particularly worthy of notice is that the change did not occur quite simultaneously in all spots, but progressively later and later as we proceed in order of increasing longitudes. This progressive nature of the change has been indicated on Plate VIII. by means of the thick broken line A to B. It is due in great measure to this remarkable change that the mean rotation-period of the South Equatorial spots was so much longer in 1888 than it had been in 1887. The rotation-period of the South Equatorial spots had been increasing in length ever since 1879, and we may gather from the curious change which has just been described that this increase did not take place regularly, but by fits and starts.

Besides this great general change, some other interesting, if more local, changes will be revealed by Plate VIII. We may notice, for example, a tendency for a particular spot, such as IV., to temporarily divide into two, and even for one of the resulting components to again subdivide, the whole subsequently re-uniting again to form a single spot. Another very interesting and characteristic feature is the manner in which if one spot is affected by a sudden change, the neighbouring spots are also more or less affected by a similar change. In other words, this indicates that an invisible and probably deep-seated change of some kind has occurred affecting not simply a single spot but a considerable area of the planet. A third interesting feature is that if two spots should separate from one another, a new spot ultimately makes its appearance in between. As, for example, the dark spot which temporarily formed when the white spot IV. divided into two. Possibly it would be more correct in this case to say that to the formation of the dark spot was due the division of the spot IV. into two spots.

Attention should be particularly directed to the fact that in many of the largest and most sudden changes the observations are both numerous and accordant, so that it is impossible that such great changes can be ascribable to errors of observation, nor can they be attributed merely to variations in the appearance of the spots, or to different reference points having been observed. It is very fortunate that the month of May was unusually fine, so that many observations are available about the time of the great change which occurred then.

In 1887 the mean rotation-period from 21 South Equatorial spots was $9^h\ 50^m\ 22^s{\cdot}4$ *. In 1888 it was $9^h\ 50^m\ 27^s{\cdot}85$, also from 21 spots, an increase of $5^s{\cdot}45$. As already mentioned, this increase was largely due to the remarkable change that occurred in May.

I have not attempted to identify any of the equatorial spots observed in 1888 with those seen in the previous year. In order to do this with satisfaction it is necessary to have the results of not less than three consecutive years available, and four would be better.

Attention is again called to the fact that the longitudes in this subsection are always those of System I. of Marth's Ephemeris, and not those of System II.

* *Z. F.* vol. i. p. 111.

Dark South Equatorial Spot I.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 25	14 25	3	344·8	L, vD, well def.	141
Apr. 1	13 34	2	341·6	mL, mD, not well def.	143
„ 3	14 51	4	345·6	Rather S, D, nearly R, well def.	144
„ 6	11 49	dup	349·6	mL, mD.	147
„ 8	12 52	4	344·7	L, vD, well def.	150
„ 26	13 55	4	353·8	vL, D, m well def.	156
May 1	12 04	5	358·0	L, vD, well def. Time by dup transit = $11^h\ 58^m{\cdot}5$.	161
„ 3	13 18·5	5	360·2	vL, eD, v well def, oblong.	166
„ 5	14 36	5	364·3	vL, vD, v well def, irr in shape.	169
„ 10	12 41	3	366·1	Rather L, F, v ill-def, a mere vestige of what it was.	170
„ 21	14 05	3	359·5	mL, vD, well def.	181
„ 24	11 00·5	5	362·1	Rather S, vD, v well def, nearly R.	183
June 2	11 30·5	5	365·7	Rather S, vD, R, well def.	191
„ 16	9 55·3	4	364·3	Rather L, vD, well def.	197
July 18	9 35	est	375·8	mL, not vD, diffuse.	207

R = $9^h\ 50^m\ 28^s{\cdot}42$ (280 rot.). This was a very conspicuous spot generally, and a very interesting one owing to its connection with the dark North Equatorial spot 27, and the enormous changes in appearance which it underwent, as will be seen from the figures of Plate III. At times nearly round, it was at other times most irregular in shape, whilst on May 3 it was almost rectangular and exceedingly large. On May 5 it was also described as very large and very dark; but only five days later a great change was recorded, the spot being described as faint and very ill-defined, "a mere vestige of what it was a week before"; whilst on May 12 it could not be seen at all, although it was specially looked for. The night, however, was not good. Later on it recovered much of its former blackness, though not its former magnitude. The spot was throughout joined to spot 27 by a broad dark streak. This streak and the last-mentioned spot likewise varied much in plainness, and that in such a manner as to indicate that the connection between the two spots was probably real, and not merely apparent. The inclination of the connecting streak to the planet's meridian also varied from time to time, doubtless owing to the fact that the motion of neither spot was quite uniform, as will be gathered from Plates VII. and VIII. In fact the relative and absolute changes in position and appearance of these two spots are very instructive.

White South Equatorial Spot II.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 25	14 50	3	359·9	eB, L, v wh.	141
Apr. 1	14 09	2	3·3	mL, B.	143
„ 3	15 21	2	3·9	mL, B.	144
„ 6	12 13	4	4·3	L, eB, wh.	147
„ 8	13 20	3	1·8	mL, eB, v wh, R.	150
„ 26	14 19	4	8·5	mL, eB, R.	156
May 1	12 26	3	11·5	mL, B.	161
„ 3	13 44·5	4	16·1	mL, vB. Times by two dup transits = $13^h\ 50^m$ and $13^h\ 46^m$.	166
„ 5	14 55	5	15·8	L, eB, wh.	169
„ 10	13 01·5	4	18·6	mL, vB, wh.	170
„ 12	14 13	2	19·0	mL, B.	173
„ 13	9 52	est	18·2	mL, eB, wh, nearly R.	174
„ 15	11 09	3	21·9	L, eB, v wh.	177
„ 19	13 30·5	2	21·8	mL, eB, v wh.	178
„ 21	14 44	2	23·3	Rather S, eB, R, disc-like.	181
„ 22	10 22	1	21·9	Def e confused. East wind.	..
„ 24	11 30	3	20·1	mL, vB, wh.	183
June 2	12 07	1	28·0	mL, vB, wh.	191
„ 14	9 27	2	30·4	mL, B.	196
„ 16	10 29	2	24·8	mL, mB, wh.	197
„ 30	9 10	3	32·6	mL, B.	201
July 18	10 12	2	38·4	mL, vB.	207

R = $9^h\ 50^m\ 29^s{\cdot}18$ (280 rot.). This was also a very conspicuous and a brilliant spot, at times almost disc-like in appearance, so as to resemble a satellite when just entering upon the disc of Jupiter. As with most of the equatorial spots, however, there were large fluctuations in brightness. It is noteworthy that between April 8 and May 5 a bright spot was always to be seen opposite to it in the great central rift of the South Equatorial belt, so that the inference is that the spot in the rift moved at the same rate as spot II., though this is not in accordance with some recent investigations of Molesworth on the motions of the white spots in this rift. It is quite possible, however, that the motion of the material in this rift is not always the same, the region being just on the borderland of two currents differing widely in velocity.

Dark South Equatorial Spot III.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 25	15 20	2	18·2	Rather S, D.	141
Apr. 1	14 32	1	17·3	Rather S, F.	143
„ 3	15 44	3	17·9	mL, D.	144
„ 6	12 37	4	18·9	Rather L, vD.	147
„ 8	13 49·5	4	19·8	mL, vD.	150
„ 13	11 53	3	20·5	L, vD, v conspicuous.	151
„ 26	14 43	?	23·1	L, D, well def. Time by dup transit = $14^h\ 43^m$.	156
May 1	12 46	4	23·7	Rather S, D, well def.	161
„ 3	14 06	4	29·2	mL, D, well def. Time by dup transit = $14^h\ 10^m{\cdot}5$.	166
„ 5	15 20	4	31·1	mL, D, well def. Time by dup transit = $15^h\ 20^m$.	169
„ 10	13 29	3	35·4	mL, D, well def.	170
„ 13	10 22	3	36·3	mL, vD, well def.	174
„ 15	11 38	1	39·6	Rather F, ill def.	177
„ 20	9 39·5	1	39·2	Inconspicuous.	179
„ 24	12 14	2	46·9	mL, vD, well def, nearly R.	183
„ 26	13 22	2	45·2	Rather S, D, well def, nearly R.	..
„ 31	11 10	3	42·6	L, D, much extended E and W.	188
June 2	12 28	1	40·8	mL, D, well def, elong E and W.	191
„ 14	9 55	1	47·4	mL, not vD.	196
July 16	9 14·6	dup	47·0	mL, vD, well def, nearly R.	206
„ 18	10 38	3	54·3	L, D, nearly R.	207
Aug. 31	7 30	1	57·0	mL, D.	213

R = $9^h\ 50^m\ 27^s{\cdot}60$ (387 rot.). The normal appearance of this spot was that of a nearly circular, blackish spot, but one very interesting change occurred, namely its temporary segmentation or division into two spots. This change, which occurred at the end of May, is well shown by Plate VIII. There is only one actual observation of two distinct or separate spots, namely on May 24, when the companion spot was observed to transit at $11^h\ 49^m$, but the subsequent observations show that the tendency to duplication or gemination existed for more than a week after this date. On May 31 the spot was not only much extended in an east and west direction, but suspicions of duplicity were expressly noted.

White South Equatorial Spot IV.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 21	13 30	2	37·9	Rather S, vB.	140
„ 25	15 57	3	40·8	Not vL, elong E and W.	142
Apr. 1	15 16	2	44·1	Rather S, mB, elong E and W.	143
„ 3	16 29	3	45·4	Rather S, not vB, elong E and W.	144
„ 6	13 23	2	46·9	mL, B, v wh, elong E and W.	147
„ 13	12 28	2	41·9	L, vB, v wh, elong E and W.	151
„ 26	15 12	3	40·8	L, vB, wh, elong E and W.	156
„ 29	12 13·7	2	47·2	Rather S, B, slightly oval.	158
May 1	13 21	4	45·0	mL, vB, v wh, oval.	162
„ 3	14 30	4	43·8	mL, vB, v wh, oval. Time by dup transit = $14^h\ 31^m{\cdot}5$.	166
„ 5	15 38	4	42·1	mL, vB, wh, oval. Time by dup transit = $15^h\ 39^m$.	169
„ 10	13 45·5	4	45·4	mL, eB, wh, nearly R.	170
„ 12	14 55	2	44·6	mL, B. Def bad.	173
„ 13	10 40	2	47·2	Rather S, B, wh.	174
„ 15	12 00	2	53·0	Rather S, mB.	177
„ 19	14 33·5	4	60·2	mL, vB, v wh, elong E and W with suspicions of duplicity.	178
„ 20	10 12·5	2	59·3	mL, B, suspected dup.	179
„ 24	12 32	3	57·9	mL, vB, v wh.	183
„ 31	11 49	3	66·4	mL, vB, nearly R, v wh.	188
June 2	12 57	1	58·5	mL, vB, v wh. Def bad.	191
„ 14	10 32	3	70·0	mL, vB, wh.	196
„ 16	11 46	3	71·8	mL, vB, v wh, elong E and W.	198
„ 30	10 13	2	71·0	mL, B, wh.	201
July 16	9 49·3	3	68·2	mL, vB, v wh, nearly R.	206
„ 18	11 05±	..	70·7±	mL, vB, wh, nearly R.	207
Aug. 31	7 55	1	72·2	mL, B, v wh, R.	213

R = $9^h\ 50^m\ 25^s{\cdot}62$ (397 rot.). Usually a very conspicuous spot, there were large fluctuations in brightness as well as in its shape and appearance. The remarkable division of this spot into two, followed by a further temporary gemination, is well shown by Plate VIII. The dark spot observed on April 29 transited at $12^h\ 28^m{\cdot}7$ (wt. = 3), the time by a double transit being $12^h\ 27^m{\cdot}7$; and on May 1 at $13^h\ 40^m$ (wt. = 4), the time by a double transit being $13^h\ 41^m$. The bright spot following the above-mentioned dark spot transited on May 10 at $14^h\ 27^m$ (wt. = 3); and on May 15 at $12^h\ 32^m$ (wt. = 2).

Dark South Equatorial Spot V.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 21	13 59	3	55·5	Not vL, mD.	140
„ 25	16 20	est	54·8	vD, v well def, nearly R.	142
Apr. 1	15 42	1	60·0	Def v bad.	143
„ 13	13 07	1	65·7	S, F.	151
„ 20	12 38	3	76·6	Rather S, mD, roughly R.	154
„ 29	13 03·7	2	77·7	mL, vD, nearly R. Time by dup transit=$13^h\ 02^m{\cdot}7$.	158
May 1	14 15	2	77·9	Rather S, F. Time by dup transit=$14^h\ 16^m$.	162
„ 4	11 09	3	79·7	L, mD.	167
„ 10	14 43	3	80·5	mL, D, nearly R.	170
„ 11	10 22	3	79·7	Rather S, vD.	171
„ 15	12 44	2	79·8	Rather F, inconspicuous.	177
„ 19	14 51·5	3	71·2	mL, vD, R.	178
„ 20	10 35·5	1	73·4	mL, mD.	179
„ 27	10 01·5	4	81·2	S, D, R.	186
June 14	10 53	3	82·8	mL, D.	196
„ 16	12 06	2	84·0	mL, D, roughly R.	198
„ 30	10 34	1	83·8	S, rather F.	201
July 16	10 12	2	82·0	S, mD.	206
„ 23	9 20	1	77·6	S, D.	209
Aug. 22	7 48	est	85·3	L, D.	210
„ 31	8 17	1	85·7	Rather S, D.	213

R=$9^h\ 50^m\ 23^s{\cdot}19$ (397 rot.). The usual appearance was that of a moderately large, nearly round spot on the north side of the South Equatorial belt.

White South Equatorial Spot VI.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 21	14 25	1	71·4	mL, B.	140
Apr. 20	13 02	3	91·2	Rather S, B, wh.	154
May 1	14 35	dup	90·1	S, F.	162
„ 4	11 40	1	98·6	mL, vB, wh.	167
„ 10	15 16	1	100·6	L, eB, v wh.	170
„ 11	11 01	4	103·4	mL, eB, v wh.	171
„ 13	12 06	2	99·9	L, B, v wh.	174
„ 15	13 13	3	97·5	Rather S, B, v wh, oval.	177
„ 20	11 21	3	101·1	mL, vB, v wh.	179
„ 27	10 21	3	93·1	mL, vB, v wh.	186
„ 31	12 36	2	95·1	Rather S, mB.	189
June 14	11 16	2	96·8	mL, mB, v wh.	196
„ 30	10 50	1	93·6	mL?, B?	201
July 16	10 25	1	89·9	mL, mB, wh.	206
„ 23	9 41	3	90·8	Rather L, eB, nearly R.	209
Aug. 22	8 00	2	92·6	mL, vB.	210
„ 31	8 33	dup	95·4	mL, vB, wh, R.	213

R = 9h 50m 21s·64 (397 rot.). A very bright and conspicuous spot, at times almost disc-like. A white spot was recorded on four nights nearly opposite to it in the central rift of the South Equatorial belt.

White South Equatorial Spot VII.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
July 16	10 50	1	105·2	mL, mB.	206
„ 23	9 55	dup	99·0	mL, vB.	209
Aug. 22	8 20	2	104·8	mL, B, wh.	210

The observations do not extend over a long enough interval of time for the rotation-period to be derived with any exactness.

Dark South Equatorial Spot VIII.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 21	14 52	2	87·9	S, F, inconspicuous.	140
Apr. 20	13 15	4	99·2	Rather S, D, R.	154
May 11	11 12·5	3	110·4	S, D, R.	171
„ 15	13 32	3	109·1	Rather S, vD, nearly R.	177
„ 20	11 36·5	2	110·6	S, D.	179
„ 25	9 25	3	102·2	mL, vD, nearly R.	184
„ 27	10 40	2	104·7	mL, mD.	186
„ 31	13 00·5	3	109·8	mL, D, oval E and W.	189
June 10	9 29·5	dup	118·6	mL, mD.	193
July 16	11 05	2	114·3	mL, D, roughly R.	206
„ 23	10 24	1	116·7	L, D, elong E and W.	209
Aug. 22	8 50	1	123·1	mL, mD.	210

R = 9h 50m 25s·13 (375 rot.). A rather small but dark and usually almost round spot. The identification is certain, notwithstanding the gaps in the observations, as the adjoining spots render any misidentification unlikely.

White South Equatorial Spot IX.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 4	13 28	2	93·3	L, vB, v wh.	145
„ 11	12 50	est	98·6	L, vB.	..
„ 13	13 58	1	96·8	mL, mB, v rough obs.	..
„ 20	13 26	3	105·9	S, B.	154
May 1	14 57	3	103·5	mL, vB, wh.	162
„ 11	11 26	2	118·7	S, vF.	171
„ 15	13 44	2	116·4	Rather S, mB.	177
„ 20	11 53	2	120·6	S, mB.	179
„ 25	9 46	3	115·0	mL, vB, wh.	184
„ 27	11 02	3	118·1	mL, vB, wh.	186
June 1	9 12·5	1	123·2	mL, vB.	190
„ 3	10 21	dup	121·7	mL, vB, v wh.	192
„ 10	9 43·5	3	127·1	mL, vB, v wh.	193
„ 14	12 09	1	129·2	mL, B, wh.	..
July 23	10 53	2	134·3	mL, vB.	209
Aug. 22	9 14	est	137·8	mL, vB, wh.	210

R = $9^h\ 50^m\ 29^s{\cdot}46$ (341 rot.). Generally a conspicuous spot, but there were large variations in brightness.

Dark South Equatorial Spot X.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 20	13 55	2	123·6	S, F.	154
May 1	15 26	1	121·2	mD.	162
„ 2	11 02	3	118·5	mL, vD.	163
„ 11	11 36	1	124·8	S, mD. Seeing bad.	171
„ 15	14 06	3	129·8	L, D, v conspicuous.	177
„ 20	12 04	2	127·3	mL, D.	179
„ 25	10 07	3	127·8	vS, eD, almost black, like the sh of a satellite.	184
„ 27	11 21	2	129·7	S, vF, inconspicuous.	186
June 1	9 35·5	3	137·2	mL, pear-shaped.	190
„ 3	10 46	4	136·9	mL, vD, v conspicuous.	192
„ 10	10 05·5	4	140·6	mL, vD, R.	193
July 19	8 55	1	149·6	S, D.	208

R = $9^h\ 50^m\ 29^s{\cdot}98$ (219 rot.). This spot underwent some rather extraordinary changes in size, shape, and intensity, or degree of darkness.

White South Equatorial Spot XI.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 13	15 00	2	134·6	S, F, inconspicuous.	152
„ 20	14 15	2	135·8	S, F.	155
May 2	11 25	3	132·6	Rather S, vB, v wh, oval. Time by dup transit = 11^h 19^m.	163
„ 11	11 50	3	133·3	mL, B, wh.	171
„ 15	14 29	1	143·9	mL, B.	177
„ 20	12 20	2	137·1	mL, B, wh.	179
„ 25	10 35	3	144·9	mL, B, wh.	184
„ 27	12 04	1	155·9	mL, B, v wh.	186
June 1	10 00·5	3	152·5	mL, mB, wh.	190
„ 3	11 15	2	154·6	mL, B, wh.	192
„ 10	10 35·5	3	158·9	mL, B, wh.	193
„ 17	10 03	3	167·3	mL, B, wh.	199
July 19 ...	9 22	1	166·1	mL, vB.	208

R = 9^h 50^m $33^s·28$ (236 rot.). The spot was remarkable for its whiteness, and for the changes that occurred in its motion (see Plate VIII.). There were great fluctuations in size and brightness, as is usually the case with the bright equatorial spots.

Dark South Equatorial Spot XII.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 11	12 05	2	142·5	mL ? not D ?	171
„ 25	10 55	3	157·1	mL, mD.	184
June 1	10 22·5	3	165·9	Not L, mD.	190
„ 3	11 35	2	166·8	Rather S, mD.	192
„ 10	10 57·5	2	172·3	S, F.	193
„ 17	10 20	1	177·6	S, D, not easy.	199

R = 9^h 50^m $54^s·35$ (90 rot.). This was an inconspicuous object, and it will be seen from Plate VIII. that the observations are all grouped together just about the time of the remarkable change of motion which affected most of the spots in May. They are therefore incapable of furnishing the true period of rotation of the spot, but only the temporary and much longer rotation-period corresponding to the time of this temporary change. Comparing the first and last observations we have for this period the value given above, which is nearly half a minute longer than what may be called the normal rotation-period of the South Equatorial spots in 1888. It cannot

be doubted that if the observations had covered a longer interval of time this spot, like the others, would have shown a much shorter period of rotation. This is clearly indicated by Plate VIII. This spot, it may be mentioned, is shown on drawings made on July 18 and Aug. 25, though the transits were not observed, and its position on these drawings confirms the correctness of the foregoing statement. The rotation-period of the spot, for the reasons indicated above, has been considered as abnormal, and has been excluded in forming the mean result for the South Equatorial Spots.

White South Equatorial Spot XIII.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 29	15 15·7	2	158·2	mL, B, wh.	159
„ 30	10 52	2	155·7	mL, B, wh.	160
May 2	12 07	3	158·2	S, F. Time by dup transit = $12^h\ 01^m$.	163
„ 4	13 20	2	159·5	mL, B, wh.	168
„ 11	12 31	3	158·3	mL, vB, wh.	171
„ 20	13 02	2	162·7	Rather S, B, wh.	179
„ 25	11 17	2	170·5	Rather S, mB.	184
June 1	10 48·5	1	181·7	vS, F.	190
„ 3	12 03·5	3	184·2	mL, vB, wh.	192
„ 10	11 20·5	2	186·3	mL, mB, wh.	193
„ 17	10 39	2	189·2	mL, rather F, wh.	199
July 19	10 02	1	190·5	mL, vB.	208
Aug. 25	7 42·5	3	196·2	mL, vB, wh.	212

R = $9^h\ 50^m\ 31^s{\cdot}13$ (287 rot.). A fairly conspicuous spot, but the changes in brightness were considerable.

Dark South Equatorial Spot XIV.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 29	15 36·7	2	171·0	vS, vF.	159
May 2	12 27	4	170·4	S, D, nearly R.	163
„ 4	13 45	2	174·8	mL, mD.	168
„ 20	13 28	2	178·6	mL, D.	179
„ 23	10 19	1	178·4	vS, D.	182
June 1	11 07	1	193·0	S, eF.	190
„ 10	11 38·5	1	197·3	S, F.	193

For the same reason as that referred to under Spot XII., the observations of this spot are so distributed that they cannot give a good determination of the real period of rotation of the spot.

White South Equatorial Spot XV.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 1	14 57	1	165·0		..
Apr. 4	15 31	2	168·3	Not L, mB, v wh.	145
„ 14	11 40·5	2	171·2	L, vB, v wh.	..
„ 20	15 26	1	179·0	S, rather F, inconspicuous.	155
„ 29	15 55±	..	182·2±	mL, B, oval, v wh.	159
May 11	13 09	3	181·5	B, wh.	172
„ 13	14 18	1	180·2	L, B, conspicuous.	175
„ 20	13 50	2	192·0	mL, vB, v wh.	179
„ 23	10 32	3	186·3	mL, vB, v wh, disc-like.	182
„ 25	11 37	2	182·7	Rather S, mB.	184
June 1	11 18	2	199·7	mL, rather F, wh.	190
„ 3	12 44	2	208·9	mL, mB, wh.	192
„ 10	11 59·5	3	210·1	mL, B, wh.	193
„ 17	11 08	3	206·9	mL, B, wh.	199
„ 22	9 15	3	209·4	mL, B, wh, nearly R.	200
July 1	9 49·5	1	214·9	mL, vB.	202
„ 19	10 46	1	217·3	mL, vB, nearly R.	208
Aug. 25	8 19·5	2	218·8	mL, B, nearly R.	212

R = $9^h\ 50^m\ 30^s{\cdot}95$ (431 rot.). A brilliant and well-defined spot, at times almost disc-like, so as to resemble a satellite when just entering on the disc of Jupiter. The observations are so well distributed and so numerous that there can be no doubt as to correct identification.

Dark South Equatorial Spot XVI.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 2	13 03	3	192·3	Rather S, mD, nearly R.	165
„ 20	14 06	1	201·7	mL, mD.	179
„ 23	10 47	3	195·5	Rather L, D.	182
June 17	11 19	3	213·6	S, vD, R.	199
„ 22	9 35	3	221·6	S, D, R.	200
July 1	10 06·5	2	225·3	S, D.	202
Aug. 25	8 37·5	1	229·7	mL, D, nearly R.	212

R = $9^h\ 50^m\ 32^s{\cdot}03$ (280 rot.). Usually a rather small but dark and definite spot. It was so sandwiched between the two white spots XV. and XVII., both of which were better observed, that there can hardly be any doubt as to correct identification, notwithstanding the considerable gaps in the observations.

White South Equatorial Spot XVII.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 2	13 18	2	201·5	S, F.	165
„ 4	14 45	2	211·4	mL, B, wh.	168
„ 11	13 42	3	201·6	mL, mB, wh.	172
„ 20	14 25	1	213·3	mL, B.	179
„ 23	11 08	3	208·3	mL, B.	182
June 1	12 03	1	227·2	mL, rather F.	190
„ 13	9 27	2	232·0	mL, rather F.	195
„ 17	11 34	3	222·8	mL, B, wh.	199
„ 22	9 52	3	232·0	mL, F.	200
July 1	10 19·5	1	233·3	mL, B.	202
Aug. 25	8 50·5±	..	237·7±	mL? mB?	212

R=9^h 50^m 30^s·56 (280 rot.). Usually rather inconspicuous. Between this spot and the next white spot XVIII. a dark spot was seen on two nights, namely on Aug. 23 and Aug. 25. On the former night this spot transited at 7^h 49^m (est. transit), the corresponding longitude being 243°·9. It was also seen, probably, on May 23.

White South Equatorial Spot XVIII.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 5	12 45	2	225·4	vL, B, wh.	146
May 2	14 05±	..	229·9±	mL, conspicuous.	165
„ 11	14 36	2	234·6	mL, B, wh.	172
„ 14	11 16	3	227·8	Rather S, B, wh.	176
„ 23	11 46	3	231·4	mL, B, wh.	182
June 17	12 07	2	242·9	mL, B, wh.	199
„ 22	10 20	3	249·1	mL, B, nearly R.	200
July 1	10 54·5	1	254·5	mL, mB.	202
„ 6	8 56·5	dup	253·8	mL, mB.	203
Aug. 23	8 13	4	258·6	mL, eB, a well def, nearly R disc.	211

R=9^h 50^m 27^s·96 (341 rot.). A bright and conspicuous spot, at times almost disc-like.

Dark South Equatorial Spot XIX.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 5	13 10	1	240·7	vS, F.	146
„ 7	14 35·5	1	249·5	S, F.	149
„ 26	11 05	1	250·1	S.	156
May 2	14 33	2	247·2	vS, vF.	165
„ 11	15 03	3	251·0	mL, vD, conspicuous.	172
„ 12	10 44·5	3	251·7	L, D.	173
„ 14	11 49	3	247·9	mL, mD.	176
„ 23	12 15	1	249·1		182
June 1	12 41	3	250·3	mL, mD.	190
„ 22	10 42	2	262·5	Rather S, mD.	200
July 1	11 11·5	1	264·9	S, F.	202
„ 6	9 15·5	2	265·4	S, D, nearly R.	203
Aug. 23	8 50	3	281·2	L, D, v conspicuous.	211

R=9^{h} 50^{m} 25^{s}·58 (341 rot.). This spot offers a good illustration of the changes which the equatorial markings so frequently undergo. Prior to May 11 it was small, faint, and inconspicuous, and thus it had appeared on May 2. But on the 11th of this month it was described as moderately large and very dark and conspicuous. Further considerable changes occurred later on.

White South Equatorial Spot XX.

Date.	Transit.	Wt.	Long.	Description.	Fig
1888.	h m		°		
Jan. 29	17 38	1	239·9	mL, B, wh.	..
Mar. 1	17 15	1	249·2	Rather S, vB, v wh.	139
Apr. 3	12 36	2	263·2	L, vB.	144
„ 7	15 02	1	265·7	Rather S, F, wh, inconspicuous.	149
„ 26	11 38	3	270·2	L, vB, wh.	156
May 2	15 09	3	269·2	Rather S, B, wh.	165
„ 3	10 55	3	272·7	mL, vB, wh.	166
„ 10	10 10	1	274·0	mL, vB, v wh.	170
„ 12	11 19	3	272·8	mL, vB, wh.	173
„ 14	12 22	3	268·0	mL, B, wh.	176
„ 23	12 50	1	270·5	mL, vB, wh.	182
June 11	9 20·5	3	271·5	mL, vB, v wh.	194
„ 17	13 00	1	275·2	mL, vB, v wh.	199
„ 22	11 01	2	274·1	mL, B, wh.	200
July 6	9 34·5	2	277·0	mL, B.	203
Aug. 23	9 12·5	..	294·9	mL, B, wh. Time the mean of a dup and an est transit.	211

R=9^{h} 50^{m} 25^{s}·87 (504 rot.). A very brilliant, well-defined, and conspicuous white spot.

Dark South Equatorial Spot XXI.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 1	17 41	2	265·1	mL, D.	139
Apr. 3	13 07	2	282·1	mL, mD.	144
„ 5	14 22	3	284·6	mL, mD, nearly R.	146
„ 26	12 05	3	286·7	mL, not vD.	156
May 10	10 30	1	286·1	Rather S ?, inconspicuous ?	170
„ 12	11 38	2	284·4	Rather S, F.	173
„ 14	12 40	2	279·0	S, F.	176
June 11	9 38	4	276·0	mL, vD, nearly R.	194
„ 22	11 15	1	282·6	S, F, inconspicuous.	200
July 6 ...	9 51·5	1	287·4	S, vF.	203

R=9^h 50^m $18^s{\cdot}50$ (309 rot.). An inconspicuous spot.

White South Equatorial Spot XXII.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 1	18 08	1	281·5	mL, mB, elong E & W.	139
Apr. 26	12 22	2	297·1	L, vB, slightly oval.	156
May 1	10 29	2	300 1	mL, B, wh, elong.	161
„ 3	11 51	4	306·8	L, B, nearly R, wh.	166
„ 5	12 55	dup	302·6	L, eB.	169
„ 10	10 55	3	301·4	Rather S, mB, wh.	170
„ 12	12 06	2	301·5	mL, vB, wh.	173
„ 14	13 12	3	298·5	mL, B, wh.	176
„ 21	12 35	3	304·6	mL, vB, v wh, oval.	181
„ 26	10 43	3	308·2	mL, vB, v wh, oval.	185
June 2	9 55	2	307·4	mL, B, wh.	191
„ 11	10 35	est	316·9	mL, mB, wh.	194
July 6	11 00	3	329·1	mL, vB, wh.	203

R=9^h 50^m $31^s{\cdot}04$ (309 rot.). This was a brilliant and conspicuous spot. Prior to May 14 it was quite close to the dark spot XXI., but after this date the two spots gradually separated from one another, a new white spot making its appearance between the two, and this new spot being ultimately separated from XXII. by a new intervening dark spot (see Plate VIII.). The following observations were made of the two new spots.

Date.	Transit.	Wt.	Long.	Description.	Fig.
			White Spot.		
1888.	h m		°		
June 11	10 02·5	2	297·1	mL, B, wh.	194
July 6	10 17	2	302·9	Rather S, mB.	203
			Dark Spot.		
May 26	10 15	1	291·1	mL, mD.	185
June 2	9 32	dup	293·4	mL, D.	191
,, 11	10 18	3	306·5	Rather S, rather F.	194
July 6	10 50	3	323·0	Rather S, D, nearly R.	203

Dark South Equatorial Spot XXIII.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 1	18 35	dup	298·0	Seeing v bad.	139
,, 25	13 17	4	303·1	S, eD, v well def.	141
Apr. 1	12 31	1	303·2	Seeing v bad.	143
,, 3	13 55	3	311·4	Rather S, D.	144
,, 5	15 10	3	313·8	mL, mD.	146
,, 26	12 56	2	317·8	Rather S, F.	156
May 1	10 59·5	3	318·7	mL, D. Time by dup transit $=10^h\ 53^m$.	161
,, 3	12 14	3	320·8	vL, rather F.	166
,, 5	13 23	4	319·7	L, vD, well def.	169
,, 10	11 24	3	319·1	Inconspicuous.	170
,, 12	12 43	3	324·0	Rather S, D, well def, nearly R.	173
,, 14	13 56	4	326·4	Rather S, D, well def, nearly R.	176
,, 21	13 01	4	320·5	mL, D.	181
,, 24	9 58	2	324·0	mL, mD.	183
,, 26	11 05	2	321·6	mL, mD, nearly R.	185
June 2	10 28	3	327·6	mL, D, nearly R.	191

$R=9^h\ 50^m\ 28^s{\cdot}66$ (226 rot.). Appearance very variable.

White South Equatorial Spot XXIV.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Mar. 25	13 42·5	4	318·8	mL, eB, v wh, susp dup E and W.	141
Apr. 1	13 03·5	2	323·0	mL, nearly R, a close double with XXV.	143
,, 3	14 13	3	322·4	Rather S, vB, R, disc-like.	144
,, 5	15 25	2	322·9	mL, vB, wh.	146
,, 8	12 17	2	323·3	mL, vB.	150
,, 26	13 12	2	327·6	mL, vB, nearly R, the p spot of a double spot.	156
May 1	11 15	2	328·1	mL, B, R.	161
,, 10	11 41	2	329·5	S, F.	170
,, 24	10 20·5	3	337·7	Rather S, vB, v wh, disc-like.	183
,, 26	11 27	4	335·0	mL, vB, v wh, v well def.	185
June 2	10 50	3	341·0	mL, vB, v wh, well def, nearly R.	191
,, 16	9 20	2	342·7	Rather S, rather F.	197
July 18	9 00	2	354·5	mL, vB, well def.	207

R=9^{h} 50^{m} 29^{s}·16 (280 rot.). This was the most preceding of two spots forming a remarkable double spot, the components being so close to one another that there does not seem to have been room for the usual intervening dark spot.

White South Equatorial Spot XXV.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 1	13 13	2	328·8	The f spot of a close double spot.	143
,, 3	14 25	1	329·7	S, not conspicuous.	144
,, 8	12 34·5	2	334·0	mL, vB, v wh, R.	150
,, 26	13 27	2	336·7	Not vL, vB, wh, nearly R.	156
May 1	11 36	2	340·9	Rather S, rather F.	161
,, 3	12 46	4	340·4	mL, vB, slightly oval. Time by double transit=12^{h} 51^{m}·5.	166
,, 5	13 57	4	340·4	Rather S, eB, R, disc-like.	169
,, 10	12 00	1	341·0	Rather S, F, inconspicuous.	170
,, 12	13 11	3	341·1	mL, vB, v wh.	173
,, 14	14 21	4	340·6	mL, vB, v wh, a disc.	176
,, 21	13 34	3	340·6	mL, vB, v wh.	181
,, 24	10 38	4	348·4	Rather S, mB, v wh.	183
,, 26	11 45	1	346·0	Rather S, rather F.	185
June 2	11 04	2	349·5	Rather S, mB, v wh.	191
,, 16	9 33·3	4	350·8	mL, vB, nearly R, wh.	197
July 6	11 42±	..	354·8±	mL, B, m well def.	203
,, 18	9 14	3	363·0	mL, vB, wh.	207

R=9^h 50^m $27^s{\cdot}25$ (263 rot.). This is the following component of the above-mentioned remarkable double spot. There were considerable fluctuations in the relative brightness of the two components of this double spot, and on one occasion at least spot XXIV. could not be seen, although it was specially looked for. Nevertheless the observations on the occasions when only one spot was seen do not suggest that the two spots were observed as one object, and the observations of both spots seem to be rightly identified as here given.

Summary of South Equatorial Spots.

Spot.		Rot.-Per.	No. of Rot.	No. of Obs.
		h m s		
Dark Spot	I	9 50 28·42	280	15
White Spot	II	9 50 29·18	280	22
Dark Spot	III	9 50 27·60	387	22
White Spot	IV	9 50 25·62	397	26
Dark Spot	V	9 50 23·19	397	21
White Spot	VI	9 50 21·64	397	17
White Spot	VII	.....	..	3
Dark Spot	VIII	9 50 25·13	375	12
White Spot	IX	9 50 29·46	341	16
Dark Spot	X	9 50 29·98	219	12
White Spot	XI	9 50 33·28	236	13
Dark Spot	XII	[9 50 54·35]	90	6
White Spot	XIII	9 50 31·13	287	13
Dark Spot	XIV	.....	..	7
White Spot	XV	9 50 30·95	431	18
Dark Spot	XVI	9 50 32·03	280	7
White Spot	XVII	9 50 30·56	280	11
White Spot	XVIII	9 50 27·96	341	10
Dark Spot	XIX	9 50 25·58	341	13
White Spot	XX	9 50 25·87	504	16
Dark Spot	XXI	9 50 18·50	309	10
White Spot	XXII	9 50 31·04	309	13
Dark Spot	XXIII	9 50 28·66	226	16
White Spot	XXIV	9 50 29·16	280	13
White Spot	XXV	9 50 27·25	263	17

Mean Rotation-Period of South Equatorial Spots=9^h 50^m $27^s{\cdot}85$ (21 spots).

(v.) The Red Spot.

Only the observations for longitude are considered here. Those relating to the appearance of the spot will be found in Section VII. The observations for longitude are given below in a slightly different form to that used for the other spots, but the arrangement of the different columns

will be readily understood. The longitudes are here again those of System II. For the rotation-period I have relied entirely upon the observations of the middle of the spot, as those of the two ends appear to be peculiarly liable to systematic errors.

Observations of the Middle of the Red Spot.

Date.	Transit.	Wt.	Long.	O − C.	Notes.
1888.	h m		°	m	
Jan. 29	17 08	1	[353·5]	[+6·1]	Very rough.
Mar. 25	13 17	1	349·5	−0·5	
Apr. 1	13 58	1	346·7	−5·1	
„ 3	15 39	2	348·5	−2·1	
„ 6	13 11·5	2	350·5	+1·1	
„ 20	14 42	1	350·5	+1·2	
May 2	14 32	2	349·3	−0·7	
„ 10	11 13	2	352·3	+4·2	
„ 12	12 48	2	350·5	+1·3	
„ 14	14 24	2	349·3	−0·7	
„ 19	13 32·5	2	350·8	+1·8	
„ 27	10 07	2	349·2	−0·9	
June 1	9 12·5	1	348·1	−2·6	
„ 3	10 54	2	350·2	+0·8	
„ 10	11 37·5	1	349·1	−1·1	
„ 17	12 24	1	349·6	−0·4	

R = $9^h\ 55^m\ 40^s{\cdot}58$ (338 rot.). The residuals O − C according to this period are given in the fifth column of the above table, the mean error of an observation being $\pm 1^m{\cdot}7$ (omitting the first observation of Jan. 29, as this was a very rough one). The weighted mean time of transit of the spot for 1888, May 21, is $15^h\ 09^m{\cdot}65$ (15 obs.), with a probable error of $\pm 0^m{\cdot}36$; the corresponding longitude being $349°{\cdot}75 \pm 0°{\cdot}22$.

It will be seen that the rotation-period of the spot in 1888 was almost exactly the same as that of the ephemeris ($9^h\ 55^m\ 40^s{\cdot}63$). The longitude of the spot at the end of the observations of 1887 was about 349°, according to my observations *. This is very nearly the same as its longitude throughout the apparition of 1888, so that the observations of one year continue those of the preceding year, and hence do not tend to confirm the existence of the form of systematic error suspected by Phillips †. In 1887 the rotation-period of the spot appears to have been slightly shorter than it was in 1888; but the observations of the former year are particularly rough and unsatisfactory, owing to the abnormal prevalence of east winds in the spring and summer of that year. The observations of the middle of the Red Spot are shown in chart form, for the purpose of comparison, in Plate IX.

As already mentioned, the observations of the ends of the spot appear

* *Z. F.* vol. i. p. 96.

† *The Observatory*, 1895, p. 344.

to be peculiarly liable to systematic errors. They have not therefore been used for deriving the rotation-period. Below will be found the observed times of transit of the preceding and following ends, together with the weights, and, in the last column, the difference between the times of transit of the two ends.

Date.	Transit of prec. end.	Wt.	Transit of foll. end.	Wt.	Diff.
1888.	h m		h m		m
Jan. 29	....	..	17 31	1	..
Mar. 25	....	..	13 45·5	2	..
Apr. 1	....	..	14 25	1	..
„ 3	....	..	16 08	2	..
„ 6	12 40	1	13 38	2	58
„ 13	....	..	14 28	1	..
„ 20	14 16	1	15 05	2	49
May 2	....	..	15 00·5	2	..
„ 3	....	..	10 56	3	..
„ 10	10 40	1	11 34	3	54
„ 12	....	..	13 15	2	..
„ 14	14 00	1	14 50	2	50
„ 20	....	..	9 48·5	1	..
„ 24	....	..	13 05	2	..
„ 27	9 42	1	10 31	2	49
June 1	....	..	9 43·5	3	..
„ 3	....	..	11 22	2	..
„ 10	11 10·5	2	12 06·5	1	56
„ 13	....	..	9 34	3	..
„ 17	11 55	2	12 48	1	53
„ 22	....	..	11 58	1	..
July 16	10 57±	..	....	..	..

Transits of both ends were observed on seven nights. These give $52^{m}\cdot7$ for the time of transit of the spot from end to end, corresponding to $31°\cdot9$. This is somewhat less than the value derived from the observations of the previous year, namely $57^{m}\cdot4$, corresponding to $34°\cdot7$ *. No real change in the length of the spot is, however, probably indicated, the apparently shorter length in 1888 being due to the presence of the white patch ϵ just preceding the preceding end of the spot. With the least bit of confusion in the definition this white patch appeared to encroach upon the preceding end of the spot, thus producing an apparent shortening in the length of the latter.

The white patch ϵ referred to above is an interesting feature. In early years, when the Red Spot first attracted universal attention, the spot was sometimes described as being surrounded by a bright annulus or halo. The reality of this annulus has been questioned and ascribed to contrast,

* *Z. F.* vol. i. p. 98.

but there can be little doubt as to its reality, though it may be doubted whether it ever possessed quite the uniformity and regularity which it has been represented as having. The white patch ε was evidently a brighter portion of this annulus, and a few transit observations were made of it and are given below.

White Spot ε preceding the Red Spot.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 27	9 38	2	331·7	2 S B spots in contact nearly n and s.	186
„ 31	12 49	2	328·6	mL, B, oval E and W.	189
June 10	11 00·5	2	326·7	mL, mB, irr in shape.	193
„ 17	11 44	2	325·4	Rather L, B, elong E and W.	199
„ 22	10 43	2	320·1	L, mB, indefinite.	200
July 16	10 45	1	327·6	L, mB, brighter condensation on f side in contact with Red Spot.	206

The descriptions and drawings show clearly that decided changes occurred in the appearance of the white patch. At first small, it gradually extended or brightened up in a preceding direction. There was probably no actual shift in the position of the patch as a whole, the drawings always showing the following end in apparent contact with the preceding end of the Red Spot, and the variations in the longitude of the object shown by the observations were probably the result of its changes in size and appearance. The patch was always more or less indefinite and irregular in outline, and not suited for exact observation. As already mentioned, this bright patch was evidently a brighter portion of the annulus surrounding the Red Spot. The bright annulus is shown complete as a uniform oval ring in a drawing made by Professor E. S. Holden with the Lick 36-in. refractor on 1888, Aug. 10, $8^h\ 45^m$ to $9^h\ 12^m$, Pacific Standard time. As to the probable origin of the annulus and patch ε see Section XIII. of this volume.

(vi.) The South Temperate Spots.

The region of the South Temperate belt of Jupiter is noted for the numerous and interesting details of various kinds usually to be found there. In particular there are nearly always many small but brilliant oval spots visible there, either on the south side of the dark belt, or partially involved in the latter. Dark spots and streaks of various kinds are also common. Although some of these details were seen in 1888, yet the conditions were so unfavourable in this year that they were difficult to observe, and with one exception no marking was followed sufficiently closely to enable its rotation-period to be determined.

The exception is a curious oval dark spot, which seems to have formed

at or near the southern edge of the Red Spot. It is remarkable as having a rotation-period abnormally short for its latitude. The observations of this spot have already been published and discussed in the *Monthly Notices*, vol. lix. p. 30; to which reference may be made for further information and reproductions of the chief drawings of the spot. But the observations for the sake of completeness have been repeated below.

Dark South Temperate Spot δ.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 14	13 13	3	306·4	L, D, oval, reddish?	176
„ 21	13 50	1	301·6	L, an irr oval.	181
„ 24	11 20	2	302·1	mL.	183
„ 31	11 54	2	295·4	L, mD, oval.	188
June 10	9 52·5	3	285·6	mL, much elong, blackish?	193
„ 17	10 31	3	281·3	Not vL, much elong.	199
„ 22	9 28	4	274·7	mL, D, blackish.	200
July 6	10 40	2	265·2	S, D, blackish.	203
„ 18	10 24	2	255·3	Rather S, mD.	207
„ 23	9 32	3	254·9	S, D, m well def.	209

R = $9^h\ 55^m\ 08^s{\cdot}2$ (169 rot.). The residuals are :—

Date.	O−C.	Date.	O−C.
1888.	m	1888.	m
May 14	−1·5	June 17	+1·1
„ 21	−0·2	„ 22	−3·1
„ 24	+4·4	July 6	−5·5
„ 31	+2·5	„ 18	−1·3
June 10	−0·8	„ 23	+4·5

the mean error of an observation being $\pm 2^m{\cdot}6$.

This dark spot is interesting also for another reason. Although it cannot be directly identified with the great South Temperate Disturbance of 1889–92, owing to its abnormally rapid motion, yet this very motion, in conjunction with its comparatively sudden formation or appearance, clearly indicates that this particular region of Jupiter was already in a very disturbed state. Moreover, the longitude of the Disturbance of 1889–92 calculated back to 1888 corresponds to the longitude when the spot δ was in conjunction with the middle of the Red Spot, at which time the former and more quickly moving spot apparently made its first appearance.

The observations of spot δ have been plotted on Plate IX. The following three observations of other spots in the latitude of the South

Temperate belt were also made:—1888, Mar. 25, $16^h\ 12^m$, a dark spot (wt.=1); June 13, $10^h\ 07^m$, a very small dark spot (wt.=2); June 30, $9^h\ 13^m$, a small, moderately bright, very white spot (wt.=2). The two dark spots were on the South Temperate belt; the white spot on the south side of that belt.

(vii.) The Southern Spots.

Definite, plain and easily observable spots are not common in the high southern latitudes of Jupiter, and 1888 proved exceptionally favoured, since two such markings were visible; one of them being, moreover, a double spot of a very characteristic appearance, so that there can be no uncertainty as regards its correct identification. The observations of these two spots have been already published *, but they are repeated below for the sake of completeness.

Dark Southern Spot a.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
May 5	13 19	2	36·4	L, D, not well def.	169
,, 10	12 19	2	32·2	L, mD, not well def.	170
,, 15	11 12	1	23·7	Oval, darkish spot.	177
,, 19	14 21·5	1	20·4	mL, D, m well def.	178
,, 24	13 25	1	17·6	mL, mD, v badly def.	183
,, 27	10 53	2	17·0	Not L, F, poorly def.	186
June 3	[11 22±]	..	[7·1±]		192
,, 13	9 23	2	358·8	Not L, mD, not well def.	195
July 16	10 43	3	326·4	Two mL, mD spots lying nearly n and s on two broad D belts. n spot slightly p the other.	206

$R=9^h\ 55^m\ 01^s{\cdot}8$ (174 rot.). The residuals are:—

Date.	O−C.	Date.	O−C.
1888.	m	1888.	m
May 5	+0·9	May 27	+6·5
,, 10	+1·7	June 3	[−0·2]
,, 15	−4·6	,, 13	−0·5
,, 19	+1·5	July 16	−9·1
,, 24	+3·7		

* *A. N.* Bd. 139, col. 214.

the mean error of an observation being $\pm 3^m\cdot 8$. This is somewhat large, but there were spots on each of the two southern belts, and it is possible that sometimes one and sometimes the other of the spots may have been observed for longitude.

Dark Southern Spot b.

Date.	Transit.	Wt.	Long.	Description.	Fig.
1888.	h m		°		
Apr. 20	12 39	2	276·2	mL, rather D, m well def spot. Transit not well obs, owing to cloud.	154
May 2	12 18·5	3	268·6	mL, mD, m well def, D tail nf.	164
„ 12	10 19·5	est	260·8	mL, D, well def, D tail n susp.	173
„ 14	11 51	3	256·8	Rather S, D, well def oval spot, with a smaller companion n.	176
„ 21	12 29	2	252·7	Rather L, D, well def, with either a companion spot or a D tail nf.	181
„ 24	9 52	2	248·9	Rather S, R, blackish spot with a smaller companion n a little f.	183
„ 26	11 21	2	243·5	Same as on the 24th.	185
June 14	11 23	?	221·6	Def v bad, no description.	196
July 1	9 58·5	1	205·8	s, mD, but only seen indistinctly owing to cloud.	202

R=9^h 54^m $58^s\cdot 6$ (174 rot.). The residuals are:—

Date.	O−C.	Date.	O−C.
1888.	m	1888.	m
Apr. 20	−7·2	May 24	+5·1
May 2	+0·6	„ 26	−0·3
„ 12	[+4·4]	June 14	−4·3
„ 14	+1·4	July 1	−1·9
„ 21	+6·4		

the mean error of an observation being $\pm 3^m\cdot 4$. This is again large, but the motion of the spot does not seem to have been quite uniform, and in any case we should expect to find the observations of a spot so far south more discordant than those of one nearer the equator. It is probable, too, that in poor seeing the two components of the double spot may have been observed as one mass, but in good seeing the southernmost component only was probably observed for longitude.

The spots *a* and *b* were each measured on one night for latitude, with the result that the southernmost spot of *a* was in latitude $-41°{\cdot}55$ ($\Delta = -0{\cdot}663$); and spot *b* in latitude $-43°{\cdot}84$ ($\Delta - 0{\cdot}693$). The latitude in the latter case is that of the middle of the southernmost and largest component of the double spot. This double spot *b* was a remarkable object, there being a nearly round, well-defined, blackish spot, with a smaller and fainter companion spot north a little following it. In poor seeing the appearance was that of a single spot with a tail or train extending in a north following direction (see Plate II. fig. 3); but whenever the seeing was good enough, the two components were seen clearly separated (Plate II. fig. 4). This peculiarity rendered the marking a very characteristic one, so that the identification is absolutely certain. The observations of the two spots *a* and *b* are plotted on Plate IX., in which the strong inclination of the paths of the spots indicates their rapid drift relative to the Red Spot.

Summary of Southern Spots.

Spot.	Rot.-Per.	No. of Rot.	No. of Obs.
	h m s		
Dark Spot *a*	9 55 01·8	174	9
Dark Spot *b*	9 54 58·6	174	10

Mean Rotation-Period of Southern Spots $= 9^h\ 55^m\ 00^s{\cdot}9$ (2 spots).

SECTION VI.

SUMMARY OF RESULTS.

A LIST of the different spots observed with their computed rotation-periods will be found at the end of each sub-section of the preceding Section whenever there is more than a single spot. Only the mean values have therefore been included in the following table. This table may be said to represent or constitute the *concentrated essence* of the present work.

Table of Mean Results.

Latitude.	△.	Name of Spots.	R.	No. of Spots.
			h m s	
+ 60° to + 25°	+ ·87 to + ·42	Northern Spots.	9 55 39·43	9
+ 25 to + 10	+ ·42 to + ·17	N. Trop. Spots.	9 55 39·92	15
+ 10 to 0	+ ·17 to ·00	N. Equat. Spots.	9 50 23·88	27
0 to − 12	·00 to − ·21	S. Equat. Spots.	9 50 27·85	21
− 16 to − 28	− ·28 to − ·47	S. Temp. Spot.	9 55 08·2	1
− 28 to − 45	− ·47 to − ·71	Southern Spots.	9 55 00·9	2
[− 12 to − 27]	[− ·21 to − ·45]	Red Spot.	9 55 40·58	1

Altogether 76 spots were sufficiently well observed to enable their rotation-periods to be ascertained with more or less exactness. The first column of the above table requires some explanation. The limits of latitude are in some cases not clearly shown by the observations of 1888 alone, and consequently they have been partly fixed by assumptions based on the observations of other years. For example, the northern limit of the zone including the South Temperate Spots has been made to correspond with the southern edge of the South Equatorial belt (−16°), although, as a matter of fact, there are no observations in this particular year 1888 of markings in the bright zone between the South Temperate belt and the South Equatorial belt (the S. Tropical zone). But the assumption appears to be warranted, since observations made in 1889, and in many subsequent years, show that whenever markings are visible in the zone in question they invariably move in unison with those situated on or near the South Temperate belt, the Red Spot, and other markings intimately connected therewith, like the white patch ε, only excepted. For the great Equatorial

current, it has been assumed that the northern limit corresponded with the central rift of the North Equatorial belt, and the southern limit with the central rift of the South Equatorial belt. It is unlikely that these adopted limiting values are materially incorrect, since the latitudes of the polar edges of the two equatorial belts have been exactly fixed by the micrometer measures. It is certain that the boundaries of the different surface currents of Jupiter vary somewhat from year to year, and occasionally even in the same year; and slightly, perhaps, in different longitudes of the planet at the same time. The above table shows a gap between latitudes $-12°$ and $-16°$, corresponding to the southernmost half of the South Equatorial belt, no definite markings having been observed there in 1888.

SECTION VII.

OBSERVATIONS ON THE APPEARANCE OF THE RED SPOT.

The following notes have been condensed and extracted from the original records made at the telescope. After the date of the observation will be found, in brackets, the quality of the seeing according to the numerical scale described in Section I. It has not been thought necessary to give this information in the tables of observations of the spots contained in Section V., because the effect of good or bad seeing has usually already been more or less discounted in the weights assigned to the transits at the time of observation, but it is very necessary in descriptions of the appearance of the markings, since this appearance is greatly influenced by the quality of the seeing.

1888, Jan. 29, $17^h\ 31^m$ (Def.=2).—The spot had a distinct though feeble reddish tint. The f. portion was plainer than the rest.

Mar. 25, $13^h\ 17^m$ (Def.=3).—The spot seemed markedly darker on the sf. portion, and gave the impression of being in contact with a belt or dark material on the south. A slight reddish colour visible. Later on, when the f. end of the spot was in mid-transit, a dark streak was suspected joining the f. tip to the f. shoulder of the Hollow.

April 1, $13^h\ 58^m$ (Def.=2).—The spot gave the *impression* of being a dark ellipse, very feeble all round except on the sf. edge, where it was very dark. The interior of the p. half of this ellipse seemed to be very white, but the f. half seemed darker and was of a distinct reddish colour. The dark belt on the sf. side of the Red Spot was either in contact with or very close to the spot. A peculiarity was noticed on this night which seems worth recording. About the time when the p. end of the spot was near the C.M. the f. end was of course rather near to the f. limb of the planet. The dark sf. border of the spot was then seen as a rather narrow but well-defined and very dark curved band. This band was very sharply defined. When the centre of the spot was in mid-transit this curved band, forming the sf. border of the spot, had become greatly enfeebled. Whilst when the f. end of the spot was on the C.M. the curved band was scarcely noticeable, and had quite lost its sharply defined appearance; this being also the case when the f. end of the spot was some way past the C.M. This peculiarity would perhaps indicate that the interior of the Red Spot was depressed below the level of the edges, or at any rate of the sf. edge.

April 3, $15^h\ 39^m$ (Def.=4–5).—The outline could at times be traced all round. The np. part of the spot was paler than the rest and had a whitish tint, the remaining portion being faint reddish. The whole s. and sf. margin was darker than the rest. The s. edge of the spot was very near to a faint dark streak or belt on the south, but it did not seem to be actually in contact with it.

April 6, $13^h\ 11^m$ (Def.=3–4).—This was the most distinct view hitherto obtained of the spot this year, and although the seeing was usually confused

it was a fairly easy object with a marked reddish tint. On the south the dusky markings came down very near to the s. edge of the spot, but after a rather prolonged scrutiny I felt pretty sure that there was actually a very narrow bright interval separating the s. edge of the spot from any dark markings. The s. edge of the spot was well defined and slightly darker than the rest of the spot, except the sf. margin. There was a narrow bright interval between the f. end of the spot and the f. shoulder of the Hollow.

April 20, $15^h\ 05^m$ (Def.=3–4), power 230.—The f. end of the spot was perfectly distinct, the sf. and f. margins being edged by a dark border, and at the extreme f. tip were faint signs of the small dark spot often seen there in former years. The red colour was quite distinct, particularly in the dark border on the s. and sf. edges. The spot seemed to be actually in contact with a short dark streak or belt on the south.

May 2.—The Red Spot was closely scrutinised during its passage across the disc, the seeing being fairly good (Def.=4–5), and some sharp views being obtained. The p. end of the spot was perfectly distinct in outline, although there were dusky markings apparently in contact with its sp. side. The rest of the spot was fairly uniform in tint and also in intensity, except that the sf. border was darker, but in best seeing the whole surface of the spot showed a complicated structure of delicate details. Once or twice the little dark spot at the f. tip was thought to be visible. On the south the Red Spot seemed to be in contact with the dark markings there, but not with the darkest part of such markings. The two darkest parts were near the f. end of the spot and towards its preceding end, and both these darker parts were certainly quite separated from the Red Spot. The reddish tint of the latter was quite plain, and it is interesting to note that the dark markings adjacent to its sf. edge were also tinged with the same faint reddish tint.

May 10 (Def.=3–4).—The Red Spot was closely examined during its passage across the disc. The sf. border was slightly though not much darker than the rest. The f. one-third of the spot seemed pretty uniform in intensity and of quite a deep reddish colour. But the p. part seemed to show a large amount of delicate detail, of which nothing certain could be made out in the poor seeing usually prevailing.

May 12, $12^h\ 48^m$ (Def.=2–3).—Spot seen in outline all round, but this was more difficult on the preceding portion. The red colour was very plain. When the f. end was in mid-transit, at $13^h\ 15^m$, the end was very sharp and plainly defined. The spot seemed distinctly plainer than it had been in 1887, whilst the red colour was quite striking. The s. and sf. margins were bordered by a darker edging. The south side of the spot was apparently in contact with a dark streak (the STB?) on the south, but this was not certain.

May 14 (Def.=5–3).—The spot was carefully examined in the course of its passage across the disc, and the seeing at first being fair, some points of interest were determined. In particular a narrow dark streak (the STB?) just above or south of the Red Spot was seen *distinctly* to cut off or hide from view the extreme south edge of the spot. The north border of the streak was distinctly visible as a straight line all along, whilst the south edge of the spot could be traced up to the streak, but no further. It is obvious from this that the streak must have been above or

at a higher altitude than the south margin of the Red Spot. The following portion of the spot was darker than the preceding portion, and was of quite a deep reddish or rather pinkish colour. The sf. margin was a little but not much darker, but the outline here could be very easily seen clearly and sharply defined.

May 19, $13^h\ 32^m$ (Def.=4–5).—Cloud nearly continuous. The spot seemed to be more uniformly dark than it had been, only the s. and sf. border being much darker than the rest. The red colour was very plain, pinkish rather than red, almost salmon-colour.

May 24, $13^h\ 05^m$ (Def.=4).—The following end of the spot was dark and sharply defined, the red colour of this part of the spot being also strikingly conspicuous. Before the preceding end of the spot had reached the C.M. the detail about it was scrutinised closely, and at this time the seeing was sharp and steady for a time. The narrow dark streak (STB ?) in the latitude of the south edge of the spot was seen plainly from spot δ at least as far as the centre or middle of the Red Spot. The north edge of the streak was straight, regular and sharply defined, and this edge could be seen as a straight unaffected line distinctly across or over the Red Spot, and apparently covering or hiding the south edge of the latter from view. This was a convincing observation, demonstrating that the dark streak was at a higher level than the upper surface of the Red Spot.

June 1 (Def.=4).—The Red Spot was carefully examined during its passage across the disc with power 230. The following half was plain and well-defined, the sf. border being edged by a darker line. The colour of this part of the spot was plainly reddish and nearly uniformly tinted. At the extreme following tip was a small blackish spot. The following shoulder approached very near to the following end of the spot, and in unsteady definition it sometimes even seemed as if the tip were joined to the shoulder by a dark line. This was not really the case, however, for in best seeing a clear, bright, sharply defined space separated the two.

June 3, $10^h\ 54^m$ (Def.=4).—The outline could not be seen distinctly at the preceding end, and the interior here seemed lighter and as though composed of a rather complex and very delicate conglomeration of shadings. No reddish colour was visible for certain except near the f. end, the p. portion being whitish rather than reddish. At $11^h\ 22^m$ the following end was in mid-transit, and this part was pretty well defined and the reddish tint was pretty decided. The sf. border was edged by a dark line and at the extreme f. tip was a small blackish spot.

June 10, $11^h\ 10^m$ (Def.=2).—The preceding end, at the time in mid-transit, was seen pretty well defined at times. The interior part of the spot seemed lighter, but this was not certain. Later on the little blackish spot at the f. tip was seen.

June 13, $9^h\ 15^m$ to $9^h\ 34^m$ (Def.=6).—The best time for making observations of the surface-markings of the planets is from one hour before to an hour or an hour and a half after sunset. The seeing is then usually at its best, whilst the daylight takes off all glare. Unfortunately it is only rarely that I have been able to observe at this time. The early part of the night of June 13th was one of these favoured occasions. The seeing was really good, and the view of the Red Spot then obtained was by far the best one of the whole apparition, though the preceding portion of the spot was too far past transit to permit of this part being properly examined.

But the following half showed an unusually large amount of definite detail. The appearance on this night is that represented in Plate I. The power used was 230. The following points were particularly noticed:—At the following tip of the spot was a small, pretty dark, dusky spot, and from this point the whole sf. and south margins of the spot were edged by a dark line, but this line was of very unequal intensity. Near the dark spot at the f. tip it was plain, dark, and well defined; then it became quite faint and delicate; whilst at the south it again increased much in darkness, so as to form almost a separate detached spot. From this kind of spot a dark streak (not shown in Plate I.) of feeble intensity extended southwards, and joined it to the belt on the south. The following end of the spot appeared to approach very near to the following shoulder of the Hollow, but in best seeing a bright and perfectly neat and distinct space was visible separating the nf. edge and f. tip of the spot from the belt. The interior of the Red Spot was by no means distinct and was almost colourless. It was plainly of irregular or unequal intensity, and in particular at the sf. part, and bordered by the dark margin, there was an indefinite whitish patch (see Plate I.). The preceding portion of the spot was too far past the C.M. for a good view, but it seemed to be very delicate and colourless, and the outline was not easily traceable.

June 17.—The seeing was too bad for a satisfactory view, but the little dark spot on the f. tip was seen distinctly at times.

The observation of June 13th was so much more satisfactory than any of the others, that it seems preferable to rely almost entirely upon this observation alone in forming a description of the general appearance of the spot in the apparition of 1888. The chief points of interest are:—(1) The little blackish spot at the following tip; (2) the definite, but *irregular* edging or border to the sf. margin; and (3) the presence of faint patches or spots in the interior of the spot. Taking it altogether, the spot was certainly distinctly plainer than it had been in the previous apparition of 1887.

SECTION VIII.

OBSERVATIONS ON THE APPEARANCE OF THE BELTS.

Plate I. shows the general arrangement and appearance of the belts in 1888, as derived chiefly from the sketches and measures. The following are a few notes referring more particularly to the same:—

1888, Mar. 25.—The South Equatorial belt about λ 95° (System II.) was composed of two broad, reddish bands of about equal darkness and breadth, the rift between being distinctly visible. The North Equatorial belt was likewise composed of two bands of about equal plainness, but the rift was very much wider than it was in the S. Equatorial belt.

April 4.—The Equatorial zone for some distance preceding λ 180° (System I.) presented a most monotonous appearance.

April 5.—Following spot W, the N. Equatorial belt seemed to get much fainter.

April 6, 16^h.—For some time the Equatorial zone had presented great uniformity and monotony of character, no markings of sufficient distinctness to be observed being seen, and this notwithstanding that the seeing was pretty sharp at times. The S. Equatorial belt (λ II.=100°) was composed of two fine, broad, reddish bands of about equal width and intensity, and the rift separating these two bands was perfectly clear and distinct. The white Southern spot *a* of 1887 was carefully looked for, but could not be seen, though distinct lighter and darker patches were visible near its probable position. These patches were too delicate to attempt to observe their transits.

April 20.—The south component of the S. Equatorial belt was distinctly visible (λ II.=276°), but was very faint. The region following the Red Spot showed a highly complex arrangement of delicate markings, which would necessitate the planet being in a better position for their proper observation. The rift in the S. Equatorial belt following the Red Spot was only just traceable.

May 1.—The rift of the great S. Equatorial belt was visible with perfect ease and distinctness all along (λ II.=130°).

May 2.—The South Equatorial belt at this place (λ II.=230°) was very distinctly seen double, the rift being plain. The south component was, however, rather narrower and not so red as the north component. Sometimes, in fact, it seemed to have a faint bluish tint.

July 23.—The South Equatorial belt about Long. 300° (System II.) was very plainly double, and the rift was apparently broader, as it was an easy feature. The two bands were of about equal breadth.

Aug. 25.—The N. Equatorial belt (λ II.=140°) was considerably less conspicuous than the S. Equatorial belt. The latter was no more conspicuous than it had been, or than it was in 1887.

SECTION IX.

OBSERVATIONS OF THE COLOURS OF THE BELTS.

The following descriptive notes of the colours of the belts are the actual records made at the telescope. In more recent observations I have used a numerical scale to express the degree of redness of the belts and markings on Jupiter. In this scale 0 signifies a complete absence of all red colour, and 10 the reddest markings ever observed upon the planet. As an illustration of the last-mentioned degree of redness, the Red Spot when at its maximum plainness and redness, and the short intensely red streak visible on the South Temperate belt in 1891, may be instanced. Following the verbal descriptions of the colours will be found in brackets what seem to me to be the probable corresponding degree of redness on the above-mentioned scale. But it must be remembered that these figures were not assigned at the time of observation, but eight or nine years after. Also that at the time of the observations the importance of the exact degree of redness of the belts was not fully recognised. Otherwise, no doubt, the records would have been more numerous and more carefully made.

It may be remarked that when both the equatorial belts are nearly equally red, the *relative* degree of redness of the two belts can be ascribed with a high degree of accuracy, probably to within a tenth of a degree of the scale of redness, though the absolute values are at all times much less exact.

1888, Mar. 25. $\lambda = 95°$.—The South Equatorial belt about this longitude was composed of two broad, reddish bands. The colour was a sort of rusty red. The North Equatorial belt was likewise composed of two bands of about equal plainness. The colour of this belt was likewise reddish, but of a much paler tint than that of the South Equatorial belt [NEB r=2; SEB r=4].

April 6. $\lambda = 100°$.—The South Equatorial belt was composed of two fine broad reddish bands [r=4].

April 20. $\lambda = 45°$.—The colour of the South Equatorial in this longitude, following the Red Spot, was very red [r=5].

May 12.—The south component of the South Equatorial belt just preceding the Red Spot was narrower and fainter than the north one, and did not seem to have much colour about it. Elsewhere, and especially just following the Red Spot, both components of the belt were of a beautiful deep reddish colour. The two bands forming the North Equatorial belts were also of a fine deep reddish colour [NEB r=5; SEB r=6].

July 23. $\lambda = 295°$.—The South Equatorial belt in this longitude was very plainly double. The colour of both bands, which were of about equal breadth, was strongly reddish [r=5].

Aug. 22. $\lambda = 45°$.—The reddish colour of the South Equatorial belt was about as intense as at any time in 1888, and as it was in 1887 [r=6].

Aug. 23. $\lambda = 200°$.—The South Equatorial belt was the same as it had been during the apparition and in the previous year. The colour (red) was no deeper or more pronounced [r=5].

The following little table gives the redness of the two equatorial belts according to the numerical scale referred to above, the mean date being 1888·4:—

REDNESS OF THE EQUATORIAL BELTS.

1888. Mar. 25	.....	NEB = 2	SEB = 4
Apr. 6	.....	„ = ..	„ = 4
„ 20	.....	„ = ..	„ = 5
May 12	.....	„ = 5	„ = 6
July 23	.....	„ = ..	„ = 5
Aug. 22	.....	„ = ..	„ = 6
„ 23	.....	„ = ..	„ = 5

Mean values :—NEB=3·5 (2 obs.); SEB=5·0 (7 obs.).

SECTION X.

MISCELLANEOUS OBSERVATIONS.

(1) On the Form of the Shadow of Satellite III.

When observing Jupiter on the night of 1888, July 6, my attention was arrested by the peculiar form or shape of the shadow of Satellite III., which was then in course of transit across the disc of the planet. The shadow at the time was slightly past mid-transit, and instead of being round, it was considerably elongated in a north and south direction, or more exactly in a direction from sp. to nf. (see Plate III. fig. 11). The shadow being near the north limb of Jupiter, this departure from circularity was thought at first to be due to some kind of deception, analogous more or less to the well-known "black drop" appearance attending a transit of Venus; and my attention being taken up with other objects, not much notice was paid to it. However, when the shadow was beginning to pass off the disc, to my surprise it had the appearance depicted in Plate III. fig. 12. The shadow was even narrower in proportion to its length than it had been before, so that a long bright promontory or horn was formed at its preceding side. The direction of the elongation appeared to be the same as before. Power 150 was used, and though definition was bad, yet at times sharp and distinct views could be obtained, so that the elongated shape was clearly not due to any deception. The shadow, it should be observed, was not black all over, but had a sensible penumbra.

Although the reason for this peculiar appearance of the shadow did not occur to me at the time, yet the explanation of it is extremely simple. It was due simply to the fact that, excepting about the times of opposition and conjunction, the Earth and Sun are not even approximately in the same straight line with Jupiter. The geometrical explanation of the problem has been considered by Professor J. M. Schaeberle in the *Astronomical Journal*, vol. xiii. p. 146; and by Mr. C. T. Whitmell in the *Journal of the British Astronomical Association*, vol. viii. p. 32. The latter has particularly considered the circumstances attending the transit which I observed in 1888, with the result that, "at the beginning of transit, the width of the shadow at the E. limb would be about 3681 miles, and, at the W. limb, at the end of transit, about 1450 miles, the height being pretty constant at about 2319 miles." The theoretical width of the shadow at the end of the transit would therefore have been only about $\frac{5}{8}$ of the height. Since the above observation I have frequently noted the non-circular shapes of the shadows of the satellites. But what is really remarkable is that a phenomenon so easily observed should so rarely have been noticed.

(2) Occultation Reappearance of Satellite II.

For various reasons I have seldom paid attention to the observation of the phenomena of the satellites. For some reason or other, however, the occultation reappearance of Satellite II. on the night of 1888, May 5, was recorded as under :—

$14^h\ 55^m$	Gr. m. t.	First seen.	Power 320. Limb very unsteady.
14 57	„	Clear ?	

The *Nautical Almanac* time of reappearance is $14^h\ 55^m$.

SECTION XI.

THE EQUATORIAL WISPS OR STREAKS.

The dark streaks, or wisps as they have been termed, crossing the bright Equatorial zone have attracted much attention during the last few years. One observer in particular, Mr. Scriven Bolton, of Leeds, has particularly studied these markings, and a remarkable uniformity in the arrangement of the wisps as described by him has been the subject of considerable controversy. The conclusions of this diligent observer, who seems to have been most successful in detecting the wisps, have apparently been summarised in a short note published by him in November 1906, entitled "A Note on the Equatorial Uniform Markings," accompanied by two charts and 12 beautifully executed drawings. Reference to this valuable note should certainly be made by anyone engaged in investigating these wisps, and the other markings with which they seem to be connected *.

Shortly, the conclusions come to by Bolton may be stated as follows :— On the north side of the South Equatorial belt are 24 dark spots arranged at nearly exactly equal distances round the planet, and on the south edge of the North Equatorial belt a similar number of dark spots are also arranged at nearly exactly equal distances apart. From each of the last-mentioned spots two dark wisps proceed, one in a south preceding direction to a dark spot on the north side of the South Equatorial belt, and the other in a south following direction to another dark spot on the north edge of the South Equatorial belt. These wisps invariably make an angle of about 45° to the equator of the planet. Since by this arrangement one wisp is always crossed by another one near the equator, the net result is that the bright Equatorial zone is apparently crossed by a series of X-shaped streaks regularly arranged. The appearance is consequently roughly something like this— XXXXXXXXXXX —the dark spots on the equatorial edges of the dark belts lying between the crosses. Since the dark spots are said to be at equal distances apart, the crosses are likewise regular and at equal distances, and consequently the whole appearance has a most unnatural uniformity. The opposite dark spots, occupying nearly similar longitudes, are, however, said to be "never linked directly together by the wisps, because the latter invariably branch out from the S. spots at an angle of about 45° to the Equator, and terminate in the N. spots, whose longitudes are intermediate to those of the S. belt."

Since the equatorial wisps were observed to some extent both in 1887 and 1888, it will be interesting to see how far the observations of these two years tend to confirm the remarkable uniform system of wisps described by Bolton. For the observations of 1887 reference may be made to Vol. I.

* I am indebted to Mr. Bolton for a copy of this valuable note, which was apparently privately printed. Many other observations and drawings on the subject of these apparently uniform markings have also been published by this observer in the *English Mechanic* and in the *Journal of the British Astronomical Association.*

of these 'Fragments,' p. 54, and the Chart, Plate I. It will be seen from the latter that there were 10 wisps seen extending in a north following direction from dark spots on the north side of the South Equatorial belt to the North Equatorial belt, and generally to a spot on the latter belt. Roughly they may be said to make an angle of 45° to the planet's equator. There were also two dark wisps running nearly due north and south, and joining opposite spots occupying nearly similar longitudes.

In 1888 (see Plate I.) there were nine or ten of these oblique wisps seen extending in a north following direction from dark spots on the north side of the South Equatorial belt to dark spots on the south side of the North Equatorial belt. But a great development had taken place in the number of the wisps having approximately a meridional direction. There are also at least two wisps which may be said to extend in a north preceding direction from spots on the north edge of the South Equatorial belt to spots on the south edge of the North Equatorial belt, and making roughly an angle of 45° with the equator.

Comparing the system of wisps as observed in 1887–8 with the exquisitely executed drawings and charts of Bolton, we shall see that there is a close *general agreement* with respect to the direction and appearance of the oblique wisps. The oblique wisps of the Chart of 1887 may be said to represent one half of the system of wisps described by Bolton, bearing in mind that this observer has delineated a much larger number of wisps. The Chart of 1888, again, may be said to show not only this half of the system, but in part also the other half of the interlacing system of wisps.

But when we look into details we find that the wisps as seen in 1887–8 lack the extreme uniformity of aspect described by Bolton. There are considerable differences in the angles which the various wisps make with the equator, and the spots, whether on the north or the south side, are more irregularly placed. The only conclusion possible is, that while my observations of 1887–8 fully confirm the existence and *general appearance* of the wisps as represented by this observer, yet they fail to confirm, or rather may be said to negative, the extreme uniformity of arrangement and aspect described by him. In one respect, moreover, namely in showing the existence of wisps having a nearly meridional direction, they are directly opposed to his observations and conclusions. It by no means follows, however, that the meridional wisps are always visible, and in fact in 1888 it was only in the latter part of the apparition that they attained to great importance. But of the real existence of the oblique wisps and their roughly regular arrangement there can be no doubt whatever, notwithstanding that this arrangement does not attain to the extreme uniformity and regularity claimed for it by Bolton. It is possible, too, that the appearance of regularity may be much more striking in some years than it is in others. It should be mentioned here that the detection of these wisps is largely a matter of practice, and their visibility is to a large extent independent of the size of the telescope used. An observer whose eye is out of practice will very likely fail to distinguish all but a few of the plainer wisps. My experience also agrees with that of Lowell as to the wisps having no resemblance to the dark streaks on Mars commonly known as "canals," or at any rate to the narrower and more definite canals.

SECTION XII.

ON THE RELATIVE ALTITUDES OF JOVIAN MARKINGS.

It is not intended here to go at all deeply into the important question of the relative altitudes of the different light and dark markings visible on the surface of Jupiter. In fact I should not have considered the matter at all, were it not for the fact that Section VI. of Volume I. had been devoted to the subject, so that it seems desirable to say a few words giving some idea of my later views about the matter.

The old idea was that the light regions represented the upper surface of a cloud envelope, brightly illuminated by the Sun, whilst the dark markings were due to gaps in this cloud envelope, permitting the solid and darker surface of the planet to be seen. This view would imply that the light markings are invariably at a higher level than the dark ones. In Section VI. of Volume I. and elsewhere I have given reasons, however, for believing that this view is an erroneous one, and that the dark markings are, in many cases at any rate, due to the presence of actually darker or less reflective material, and are at a higher level than the white ones.

Subsequent study has led me to somewhat modify this view of the matter, and it now appears more likely that there is comparatively little difference in level between the upper surfaces, or the surfaces that we perceive, of the two kinds of markings. If we consider the more important surface currents—the Equatorial Current, the North Tropical Current, and the South Temperate Current—the evidence seems to show that these great currents flow side by side almost, if not quite, in actual contact with adjoining currents moving with different velocities*, and at not very greatly differing altitudes, so far as their upper surfaces are concerned. The observations seem strongly to support this general view of the matter, adopting which it is not difficult to explain satisfactorily many of the more important features and changes of the visible surface of the planet. We can see, for example, how an accumulation of bright material in a white zone might easily have sufficient weight or power to break into or through a weak place in a dark zone, the material of which moves at a different velocity. By virtue of such different velocity, the white encroaching material would be drawn out into a comparatively narrow stream, penetrating, usually more or less obliquely, particularly at first, into the dark zone. Hence we get an explanation of a very common feature—the numerous narrow, bright rifts or channels penetrating more or less obliquely into the dark belts from the adjacent light zones.

* There may sometimes be a narrow region between two adjacent currents in which the material moves at an intermediate rate. For example, Molesworth's observations indicate that the spots in the great central rift of the South Equatorial belt sometimes move at a rate intermediate between that of the Equatorial Current and the Red Spot Current.

In a somewhat similar manner it is not difficult to explain the formation of some of the narrow dark streaks. It is only necessary to imagine an eruption of dark material in the North Tropical zone, just at the border of the great Equatorial Current, to explain the formation of the celebrated "Slant Belt" of 1860. It is easily seen how in such case the dark material of the eruption might be rapidly drawn out into a long streak, which would at first be a slanting streak, such as was actually observed in 1860.

Although the general or average upper surfaces of the light and dark markings appear to be at not greatly differing altitudes, it is probable that the darker spots, and possibly sometimes the brighter spots also, may be at a considerably higher altitude above this general or average surface. It is also possible that some of the small, intensely dark, red spots occasionally seen at the northern border of the North Equatorial belt may have been due to clear spaces in the atmospheric envelope of the planet. Their aspect at any rate suggests this, though it is very necessary in celestial observations to beware of appearances, above all, perhaps, where planetary markings are in question. The dark streaky material of the present South Temperate Disturbance would appear to be at a higher altitude than the average bright surface of the South Tropical zone.

As already stated, however, it is not intended to go at all deeply into this important subject at present, and the foregoing remarks are intended chiefly to show the direction towards which more recent views are tending, rather than as an indication of any fixed or definite theory or hypothesis. Moreover, any such hypothesis is certain always to be largely a matter of opinion, and of a more or less speculative character, and speculative hypotheses and considerations do not appeal much to the simple observer.

SECTION XIII.

THE PRINCIPAL GREAT SURFACE CURRENTS OF JUPITER IN 1887-8; COMPARISON WITH LATER RESULTS.

Plate IV. shows in diagram form the chief surface currents of Jupiter as derived from the observations of the two oppositions of 1887 and 1888. The observations of the two years have been combined chiefly for the reason that the only spot in the South Temperate Current observed in 1888 was the abnormal spot δ, so that a misleading impression might have been produced if the results of the last-named year alone had been taken into consideration.

The nature of the diagram will be easily understood. Most of the markings on Jupiter have a rotation-period approximating roughly either to System I. or to System II. of Marth's Ephemeris. The latter system, which practically corresponds to the rotation-period of the Red Spot, is taken as the standard of comparison. Both the spot and all other regions of the planet having a similar rate of rotation or drift are indicated by round dots. The direction and velocity of the drift of the other surface currents relative to the Red Spot are indicated by the direction and length of the arrows in the diagram. But the arrows representing the great Equatorial Current are not on the same scale as the others, but are almost necessarily relatively much shortened. The arrows representing the Equatorial Current if on the same scale as those indicating the extra-equatorial currents would be about equal in length to the equatorial diameter of the planet. The actual observed rotation-periods* of the different currents, as derived from the observations of 1887–8, are shown on the left-hand side of the diagram, whilst on the right-hand side are the names given to the different currents.

The situations and boundaries of the currents with respect to the belts of Jupiter are also indicated in the diagram. It should be mentioned, however, that these boundaries are necessarily somewhat approximate, and, as has been stated in Section VI., the knowledge acquired in subsequent years has to some extent been made use of. This particularly applies to the South Temperate Current. No spot was observed in the bright South Tropical zone either in 1887 or 1888, with the exception of the Red Spot and details in connection with it. But observations in many subsequent years have shown that the markings in this zone, with the exception above mentioned, invariably move at practically the same rate as those situated on the South Temperate belt; so that it seems justifiable to continue this current up to its normal northern boundary, the southern edge of the South Equatorial belt.

* It is convenient to bear in mind that a difference of $1^s{\cdot}9$ in the rotation-period corresponds approximately to 2·1 kilometres per hour in the velocity of a surface current, except in high latitudes.

It has been assumed likewise that the southern limit of the great Equatorial Current was at the central rift of the double South Equatorial belt, and the northern limit at the central rift of the double North Equatorial belt. This is certainly very near the truth, though there is evidence to show that the limits of this current vary to a certain extent, not only in absolute latitude, but also in relation to the dark belts. Molesworth's observations indicate that the spots situated in the central rift of the South Equatorial belt move sometimes at a rate intermediate between that of the Equatorial Current and the Red Spot Current. This might well be the case if the rift is at the borderland between the two currents.

There is not so much justification for marking the southernmost component of the South Equatorial belt the same as the Red Spot. No definite spots were observed in it either in 1887 or 1888, and the presence of the Hollow in the belt opposite to the Red Spot does not necessarily justify it, since the dark material of the belt might well pass round northwards, following the curve of the Hollow, supposing it to drift at a different rate. But whenever definite spots have been observed on the southernmost band of this belt they have always shown a motion very similar to that of the Red Spot.

Since the date of the present series of observations, an enormous mass of valuable material has been accumulated, chiefly by the praiseworthy labours of Barnard, Bolton, Comas Solá, Denning, Hough, Lau, MacEwen, Molesworth, Phillips, H. Struve, and other observers, so that it may be useful to bring together here for purposes of comparison the chief determinations of the rotation-periods of the different surface currents. I confine myself here to the currents actually observed in 1887–8, and generally, for the reasons already indicated, have only included determinations *based on a considerable number of spots.* A few others based on only three or four spots have been included, either because there is no other determination in the year in question, or else for the purpose of comparison, or for some other reason. The various determinations are treated below under the heads of the different surface currents to which they relate. It is not claimed that the lists are complete *, though it is believed that not many really reliable determinations, based upon a number of spots, can have been omitted. And no attempt is made here to critically examine the mass of material now brought together, although such critical examination seems to be both desirable and necessary. Its necessity is indicated by the existence of a systematic difference between the results of Denning and Molesworth, referred to later on, and by the following difference between the results of two observers:—For the opposition of 1904–5 Molesworth derived a rotation-period of $9^h\ 55^m\ 53^s{\cdot}97$ from 9 spots at or about the south edge of the South Equatorial belt †; for the same opposition Bolton found a period of $9^h\ 55^m\ 20^s{\cdot}7$ from 21 dark spots on the south edge of the same belt ‡. It is clear from this that there must have been a complete mis-identification on the part of one or both observers. As a matter of fact, the little dark spots or projections on the south edge of

* Some more recent determinations have lately been published in the *Mem. B. A. A.* vol. xvi., too late to be included in the present lists.

† *M. N.* vol. lxvi. p. 105.

‡ *Mem. B. A. A.* vol. xiv. p. 82.

the South Equatorial belt are difficult to observe, owing to their minute size, and very easily mis-identified, owing to their striking family resemblance. Besides which they are sometimes subject to sudden changes. This illustration also serves well to point out the great importance of the publication in some form or other of *all the individual observations*, without any attempt at selection or rejection on the part of the observer. It is open to any one to reject a *published* observation, but it is very desirable that every observation should be published, however discordant it may appear to be.

It should be mentioned that in a few instances the figures given in the following tables were obtained by combining the results derived from two or three different zones of spots, giving nearly identical results, and there not being sufficient reason for believing or treating them as indicating distinct currents or sub-currents. A mean derived in this manner might differ slightly from the mean of all the individual spots. It is quite possible, however, that further observation may show clearly the existence of such sub-currents as more or less permanent features of the planet. This is particularly likely to be the case in the northern hemisphere of Jupiter, north of the North Tropical zone.

THE NORTHERN CURRENT.

Year.	Rot.-Per.	No. of Spots.	Authority.
	h m s		
1888	9 55 39·43	9	Williams, *Z. F.* vol. ii. 25.
1898	9 55 52·0	2	Phillips, *M. N.* vol. lix. 88.
1899	9 55 56·9 *	3	Phillips, *M. N.* vol. lx. 222.
1899	9 55 06·41	6	Molesworth, *M. N.* vol. lxv. 701.
1900	9 55 39·66 †	41	Molesworth, *M. N.* vol. lxv. 701.
1903–4	9 55 45·7 ‡	23	Denning, *Mem. B. A. A.* vol. xiv. 83.
1904–5	9 55 50·8	91	Bolton, *Mem. B. A. A.* vol. xiv. 82.
1906–7	9 55 41·15	9	Phillips, *M. N.* vol. lxvii. 524.

The average rotation-period is $9^h\ 55^m\ 41^s{\cdot}51$, which is very nearly the same as that of the Red Spot. But it is noteworthy that in some years two or three distinct sub-currents were observed. This was very strikingly the case in 1900, when there were three sub-currents present, ranging from $9^h\ 55^m\ 19^s{\cdot}12$ to $9^h\ 56^m\ 00^s{\cdot}21$, a difference of 41^s. In other years, in 1888 in particular, the drift of the surface material was practically uniform over the whole northern region of the planet, from latitude 10° N. to latitude 60° N.

* A fourth spot, on the NNTB, had an abnormal rotation-period of $9^h\ 55^m\ 32^s{\cdot}0$.

† Molesworth's observations of this year show three distinct sub-zones, or sub-currents, ranging from $9^h\ 55^m\ 19^s{\cdot}12$ in the North Polar region to $9^h\ 56^m\ 00^s{\cdot}21$ at the NNTB.

‡ Two distinct sub-zones or sub-currents are indicated.

THE NORTH TROPICAL CURRENT.

Year.	Rot.-Per.	No. of Spots.	Authority.
	h m s		
1887	9 55 34·5	2	Terby, *Third Memoir.*
1887	9 55 36·49	17	Williams, *Z. F.* vol. i. 111.
1888	9 55 39·92	15	Williams, *Z. F.* vol. ii. 40.
1890	9 55 34·5	5	Hough, *M. N.* vol. lii. 414.
1894–5	9 55 32·7	10	Hough, *A. N.* 3354.
1894–5	9 55 35·0	9	Denning, *M. N.* vol. lv. 476.
1895–6	9 55 33·0	2	Hough, *M. N.* vol. lx. 550.
1897	9 55 31·6	6	Hough, *M. N.* vol. lx. 551.
1898	9 55 26·3	3	Denning, *M. N.* vol. lviii. 481.
1898	9 55 26·67	6	Molesworth, *M. N.* vol. lxv. 701.
1898	9 55 26·8	3	Hough, *M. N.* vol. lx. 551.
1899	9 55 28·0	25	Phillips, *M. N.* vol. lx. 222.
1899	9 55 28·8	16	Denning, *M. N.* vol. lix. 572.
1899	9 55 29·1	3	Hough, *M. N.* vol. lx. 551.
1899	9 55 30·83	21	Molesworth, *M. N.* vol. lxv. 701.
1900	9 55 30·0	17	Denning, *M. N.* vol. lxiii. 333.
1900	9 55 30·4	10	Comas Solá, *A. N.* 3671.
1900	9 55 30·47 *	20	Molesworth, *M. N.* vol. lxv. 701.
1901	9 55 29·72	28	Molesworth, *M. N.* vol. lxv. 701.
1901	9 55 32·1	4	Comas Solá, *A. N.* 3772.
1902–3	9 55 26·72	13	Molesworth, *M. N.* vol. lxv. 701.
1902–3	9 55 29·8	10	Denning, *M. N.* vol. lxiii. 333.
1903–4	9 55 29·90	13	Molesworth, *M. N.* vol. lxv. 701.
1903–4	9 55 31·6	38	Bolton, *Mem. B. A. A.* vol. xiv. 82.
1903–4	9 55 31·9	3	Denning, *Mem. B. A. A.* vol. xiv. 83.

The average rotation-period is $9^h\ 55^m\ 31^s{\cdot}07$. This is the simple mean of the above 25 determinations, each of which is based on a number of spots. There has clearly been a systematic change in the length of the period, though whether such change may turn out to be ultimately of a periodic nature or not is uncertain at present. The period reached a maximum of length in 1888, when it was very nearly as long as that of the Red Spot. From this date it seems to have decreased, more or less constantly, to a minimum about ten years later, after which there was a slow but steady increase in the length of the period. Generally the separate determinations by different observers in the same year are in satisfactory agreement. The three determinations by Denning, Molesworth, and Hough, for example, in 1898 agree within a fraction of a second. So do the three by Denning, Comas Solá, and Molesworth in 1900. Occasionally we find differences amounting to two or three seconds, but such differences must be expected to occur sometimes, and they can have no influence upon the conclusions to be drawn. With the single exception of 1888, the

* Six other spots in the North Tropical Zone gave a period of $9^h\ 55^m\ 21^s{\cdot}46$. This Molesworth considered as "abnormal."

surface material of this latitude had a very decided drift relative to that of the great Equatorial Current on the one hand, and to that of the region lying to the north on the other hand, so that the current must certainly be considered to be a *permanent feature* of the planet.

THE EQUATORIAL CURRENT (NORTH).

Year.	Rot.-Per.	No. of Spots.	Authority.
	h m s		
1887	9 50 40·06	5	Williams, *Z. F.* vol. i. 111.
1888	9 50 23·88	27	Williams, *Z. F.* vol. ii. 55.
1899	9 50 28·2	4	Comas Solá, *A. N.* 3596.
1901	9 50 25·29	44	Molesworth, *M. N.* vol. lxv. 701.
1902–3	9 50 41·97	3	Molesworth, *M. N.* vol. lxv. 701.
1904–5	9 50 28·6	24	Bolton, *Mem. B. A. A.* vol. xiv. 82.
1906–7	9 50 41·8	18	Phillips, *M. N.* vol. lxvii. 524.

The above figures show that considerable differences occur in the rate of drift of the northern portion of the great Equatorial Current relative to that of the southern or main part of the same current, but there appears to be no *permanent* difference, so that we cannot consider this northern portion to constitute a distinct current, nor even a permanent sub-current. The probability is that the northern portion of the current is liable to occasional retardation, possibly owing to its proximity to the more slowly moving North Tropical Current.

THE EQUATORIAL CURRENT (SOUTH).

Year.	Rot.-Per.	No. of Spots.	Authority.
	h m s		
1887	9 50 22·4	21	Williams, *Z. F.* vol. i. 111.
1888	9 50 27·85	21	Williams, *Z. F.* vol. ii. 73.
1897	9 50 34·6	8	Williams, *M. N.* vol. lviii. 13.
1898	9 50 23·6	23	Denning, *M. N.* vol. lviii. 481.
1898	9 50 24·0	38	Williams, *M. N.* vol. lx. 468.
1898	9 50 24·2	19	Phillips, *Mem. B. A. A.* vol. vii. 89.
1899	9 50 23·06	42	Molesworth, *M. N.* vol. lxv. 700.
1899	9 50 24·1	9	Comas Solá, *A. N.* 3596.
1899	9 50 24·6	27	Denning, *M. N.* vol. lix. 572.
1900	9 50 22·36	46	Molesworth, *M. N.* vol. lxv. 700.
1900	9 50 22·45	22	Comas Solá, *A. N.* 3671.
1900	9 50 24·1	18	Denning, *M. N.* vol. lxiii. 333.
1901	9 50 25·89	56	Molesworth, *M. N.* vol. lxv. 701.
1901	9 50 29·1	28	Denning, *M. N.* vol. lxiii. 333.
1901	9 50 31·6	17	Comas Solá, *A. N.* 3772.
1902–3	9 50 25·90	18	Molesworth, *M. N.* vol. lxv. 701.
1902–3	9 50 26·7	24	Denning, *M. N.* vol. lxiii. 333.
1903–4	9 50 22·72	42	Molesworth, *M. N.* vol. lxv. 701.
1903–4	9 50 27·9	28	Denning, *Mem. B. A. A.* vol. xiv. 83.
1904–5	9 50 29·4	48	Bolton, *Mem. B. A. A.* vol. xiv. 82.
1906–7	9 50 27·1	36	Phillips, *M. N.* vol. lxvii. 524.

The simple mean of the above 21 determinations, based upon the observations of no less than 591 spots *, is $9^h\ 50^m\ 25^s{\cdot}89$. There seems to have been little change in the rate of motion of the Equatorial Current in the twenty years from 1887 to 1906–7. Temporary fluctuations, resulting in a change of a few seconds in the period of rotation, occurred from time to time, but nothing that can be described as of a permanent or periodical nature. Generally the determinations of two or more observers in the same year are in satisfactory agreement. But there is one rather remarkable instance of a systematic difference between the results of two different observers, as will be seen from the following figures:—

Year.	Denning. R.	No. of Spots.	Molesworth. R.	No. of Spots.	D.–M.
	h m s		h m s		s
1899	9 50 24·6	27	9 50 23·06	42	+1·54
1900	9 50 24·1	18	9 50 22·36	46	+1·74
1901	9 50 29·1	28	9 50 25·89	56	+3·21
1902–3	9 50 26·7	24	9 50 25·90	18	+0·80
1903–4	9 50 27·9	28	9 50 22·72	42	+5·18

It will be seen that the difference D.–M. is always in the same sense. A possible explanation of this difference is that, in cases of doubtful or uncertain identification, one observer may have had a leaning or bias, more or less unconscious no doubt, towards a long period, or the other perhaps a leaning towards a short period. If this explanation is correct, we should be well advised in reducing our observations to reject all results that appear to be in the least bit uncertain with regard to the all-important question of correct identification. There will usually be plenty of spots remaining to give a good determination, even if half the number should have to be rejected for uncertainty.

THE SOUTH TEMPERATE CURRENT.

Year.	Rot.-Per.	No. of Spots.	Authority.
	h m s		
1887	9 55 17·1	3	Williams, *Z. F.* vol. i. 111.
1888	[9 55 08·2]	1	Williams, *Z. F.* vol. ii. 77.
1898	9 55 14·90	6	Molesworth, *M. N.* vol. lxv. 700.
1898	9 55 19·4	6	Phillips, *M. N.* vol. lix. 88.
1898	9 55 20·5	4	Denning, *M. N.* vol. lviii. 481.
1899	9 55 15·94	20	Molesworth, *M. N.* vol. lxv. 700.
1899	9 55 18·6	3	Denning, *M. N.* vol. lix. 572.
1899	9 55 19·7	19	Phillips, *M. N.* vol. lx. 222.
1900	9 55 16 88	46	Molesworth, *M. N.* vol. lxv. 700.
1901	9 55 18·01	47	Molesworth, *M. N.* vol. lxv. 701.
1902–3	9 55 18·36	9	Molesworth, *M. N.* vol. lxv. 701.
1902–3	9 55 18·7	7	Denning, *M. N.* vol. lxiii. 333.
1903–4	9 55 18·7†	10	Denning, *Mem. B. A. A.* vol. xiv. 83.
1903–4	9 55 18·74	29	Molesworth, *M. N.* vol. lxv. 701.
1904–5	9 55 20·61‡	22	Molesworth, *M. N.* vol. lxvi. 103.
1904–5	9 55 21·4	102	Bolton, *Mem. B. A. A.* vol. xiv. 82.
1906–7	9 55 21·95	26	Phillips, *M. N.* vol. lxvii. 524.

* Counting each series of observations of a spot as a separate spot, but where there are two or more results in the same year, the same spots, more or less, may have been included in more than one determination.

† Two other spots gave an "abnormal" value of R, namely $9^h\ 55^m\ 12^s{\cdot}0$.

‡ Two other spots gave an "abnormal" value of R, namely $9^h\ 55^m\ 27^s{\cdot}78$.

The single spot observed in 1888 had an abnormally short period. The remaining 16 determinations give $9^h\ 55^m\ 18^s{\cdot}72$ as the average rotation-period of the South Temperate Current.

THE SOUTHERN CURRENT.

Year.	Rot.-Per.	No. of Spots.	Authority.
	h m s		
1888	9 55 00·2	2	Williams, *Z. F.* vol ii. 80.
1898	9 55 05·91	4	Molesworth, *M. N.* vol. lxv. 700.
1898	9 55 06·3	2	Phillips, *M. N.* vol. lix. 88.
1899	9 55 05·60	3	Molesworth, *M. N.* vol. lxv. 700.
1899	9 55 07·0	7	Phillips, *M. N.* vol. lx. 222.
1899	9 55 09·2	2	Denning, *M. N.* vol. lix. 572.
1900	9 55 06·60	21	Molesworth, *M. N.* vol. lxv. 701.
1901	9 55 06·14	21	Molesworth, *M. N.* vol. lxv. 701.
1902–3	9 55 04·01	3	Molesworth, *M. N.* vol. lxv. 701.
1903–4	9 55 06·35*	9	Molesworth, *M. N.* vol. lxv. 701.

The mean value of R from the above ten determinations is $9^h\ 55^m\ 05^s{\cdot}71$.

The existence of these great permanent surface currents on Jupiter enables us to explain several things that otherwise are almost inexplicable. The probable origin and explanation of the numerous narrow bright rifts or channels penetrating into the dark belts have already been referred to. We have further a simple and rational explanation of the presence of the great deep bay or hollow in the South Equatorial belt opposite the Red Spot. The diagram, Plate II. fig. 5, will show this. We have, in the first place, the great Red Spot; and secondly, surrounding it on all sides the South Temperate Current, the material of which flows steadily past the spot in the direction indicated by the arrows. The spot acts, then, in precisely the same manner as would an island emerging above the waters of a stream. It diverts the material of the South Temperate Current, just as the water of the stream would be diverted by the island. The white material of the South Tropical zone, or the greater proportion of it, passes round the north side of the Red Spot, and forces northwards, or removes, the dark material of the South Equatorial belt, thus forming the well-known "Hollow" in the belt. In like manner the water of our imaginary stream would wear away or remove the land opposite the island, and form a bay or hollow in the boundary banks of the stream.

It should be remarked that the South Temperate Current usually extends for some distance south of the dark South Temperate belt, which is therefore included in that current. Hence we do not generally find any bay or hollow in this belt opposite the Red Spot. But we do see very evident signs of *compression* in both the white and dark markings as they drift past above the Red Spot. The material of the South Tropical Current would naturally seek the line of least resistance, and this would pretty evidently be on the Equatorial side of the Red Spot. For observation has shown us

* Also 5 additional spots gave an "abnormal" rotation-period of $9^h\ 55^m\ 12^s{\cdot}25$.

that the equatorial regions of the planet generally are in a more disturbed state than the extra-equatorial regions; and hence that the material must be in a more mobile or plastic condition there than it is nearer the poles. The white material of this zone therefore passes or forces a passage round the north side of the Red Spot in preference to the south side.

The Red Spot is not stationary, but moves about, not only in latitude, as Hough's measures have shown, but also in an east and west direction. It can only be likened therefore to an enormous floating island, the base of which must pretty obviously extend down into the denser or more solid regions of Jupiter. Notwithstanding these movements the Hollow always maintains very nearly exactly the same position opposite the Red Spot, which it accompanies in its movements or changes in position. The above suggested explanation of the origin of the Hollow likewise explains why this should be the case.

There is one circumstance that at first sight appears unfavourable to the foregoing explanation. The *dark* material sometimes visible in the South Tropical zone, such as that constituting the present well-known South Temperate (or Tropical) Disturbance, does not apparently pass northwards round the Red Spot, like the white material of the same zone. It appears, in part at any rate, to flow southwards by way of the South Temperate belt, though some of it may perhaps pass northward by way of the South Equatorial belt. But this cannot be held to be a real objection, since there are reasons for believing that this dark material is at a different, and probably slightly higher, altitude in the atmosphere of the planet than the white material of the same zone, though there is evidently likewise connection of a physical character between the two forms of material. And a simple explanation would be that the white material in the South Tropical zone on encountering the obstructing Red Spot is heaped up to a certain extent, and the dark and higher material in question is obliged to flow round the heaped up white material.

I should like to be able to say that I had actually seen the white material of the South Tropical zone pass along the channel between the Red Spot and the South Equatorial belt. But although I have sometimes seen brighter spots in this channel, yet I have never hitherto been able to follow one long enough to *prove* this, though such spots have certainly sometimes changed their position. Intervals of bad weather or poor seeing have always rendered it impossible to be sure whether a spot seen on one night was really identical with one visible a short time previously. But although motion of such brighter spots along the channel between the Red Spot and the belt would conclusively prove that the white material passes along this channel, yet the converse of this does not necessarily prove the contrary; and the presence of an apparently stationary white spot in the channel would not prove that the white material does not pass along it. For the presence of such an apparently stationary spot might merely be an indication of the existence of a constriction or obstruction in the channel, whereby the white material is more densely compacted at this part of the channel; or such an apparently stationary spot might be merely due to contrast.

SECTION XIV.

BIBLIOGRAPHY OF 1888.

THE following are references to the brief bibliography of 1888, so far as known to me; but this Section does not profess to be complete, owing to my not having ready access to a good Astronomical Library. It is to be hoped that this is the case, and that there is in reality much additional literature relating to the year 1888 in existence. In the following references a * prefixed signifies that the work mentioned has not been personally inspected by me. A † indicates that the drawing or record is in my possession, but has not been published hitherto to my knowledge.

ANTONIADI, E. M.—Drawing dated 1888, July 5, made with a 75-mm. refractor, and a note on the aspect of the planet. *L'Astronomie*, 1889, p. 75.

BARNARD, E. E.—Transit of the Red Spot on 1888, July 24. *Publications A. S. P.* vol. i. p. 110.

†DAVIS, G. T.—Drawing dated 1888, June 25, made with a $3\frac{3}{4}$-in. refractor. See also under DENNING.

DENNING, W. F.—"Motion of the Red Spot on Jupiter." *The Observatory*, 1888, p. 406.—Gives particulars of four transits. From two of these a period of $9^h\ 55^m\ 40^s{\cdot}24$ was derived.

DENNING, W. F.—"Report on Observations of Jupiter during the Opposition of 1887–8." *Journal of the Liverpool Astronomical Society*, vol. vii. p. 55.—Contains account of observations by G. T. Davis, W. F. Denning, and A. S. Williams.

DENNING, W. F.—Drawing dated 1888, February 12. *Journal of the Liverpool Astronomical Society*, vol. vi. p. 141.

†HOLDEN, E. S.—Drawing dated 1888, August 10, made with a 36-in. refractor. The Red Spot, nearly in mid-transit, is surrounded by a uniform bright annulus or halo.

HOLDEN, E. S., J. M. SCHAEBERLE, and J. E. KEELER.—"Observations of Jupiter and of his Satellites with the 36-in. Equatorial of the Lick Observatory." *Publications A. S. P.* vol. iii. p. 263.—Contains observations of three transits of the Red Spot and of several satellite phenomena. On two occasions the shadow spots of satellite were seen not round but oval, like as in my own observation of 1888, July 6.

KEELER, J. E.—See HOLDEN.

*KONKOLY, N. VON.—"Beobachtungen angestellt am astrophysikalischen Observatorium in O'Gyalla (Ungarn)." Bande xi. & xii.

RICCÒ, A.—"Passagi della Macchia Rossa di Giove." *A. N.* 2916.—Gives particulars of three transits of the Red Spot, and one of a white equatorial spot.

SCHAEBERLE, J. M.—See HOLDEN.

SELLS, E. P.—"Remarks on the Physical Observations of Jupiter, made at the Adelaide Observatory, 1888–93." *Monthly Notices*, vol. lvii. p. 152.—A Chart for 1888 is in the Library of the Royal Astronomical Society.

WILLIAMS, A. S.—See DENNING.

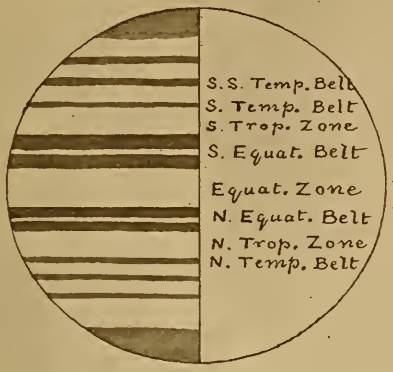


Fig. 1.

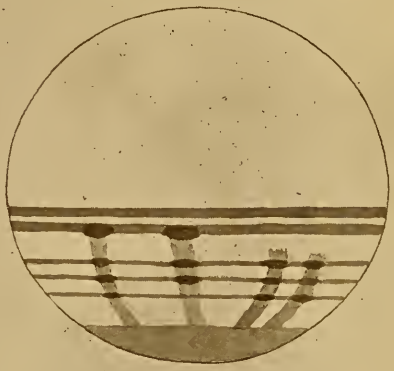


Fig. 2

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 1.

1888, April 6.

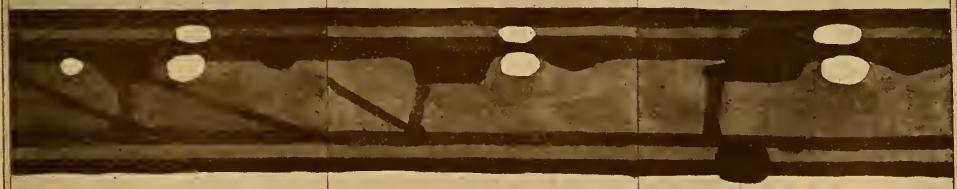
Fig. 2.

1888, April 8.

Fig. 3.

1888 April 26.

Fig. 4.



1888, May 1.

Fig. 5.

1888, May 3.

Fig. 6.

1888, May 5.

Fig. 7.

1888, May 10.

Fig. 8.

1888, May 21.

Fig. 9.

1888, May 24.

Fig. 10.

1888 June 2

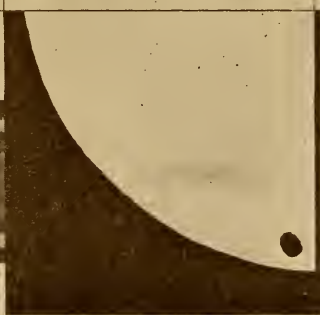


Fig. 11.

Fig. 12.

SURFACE CURRENTS OF JUPITER IN 1887–8.

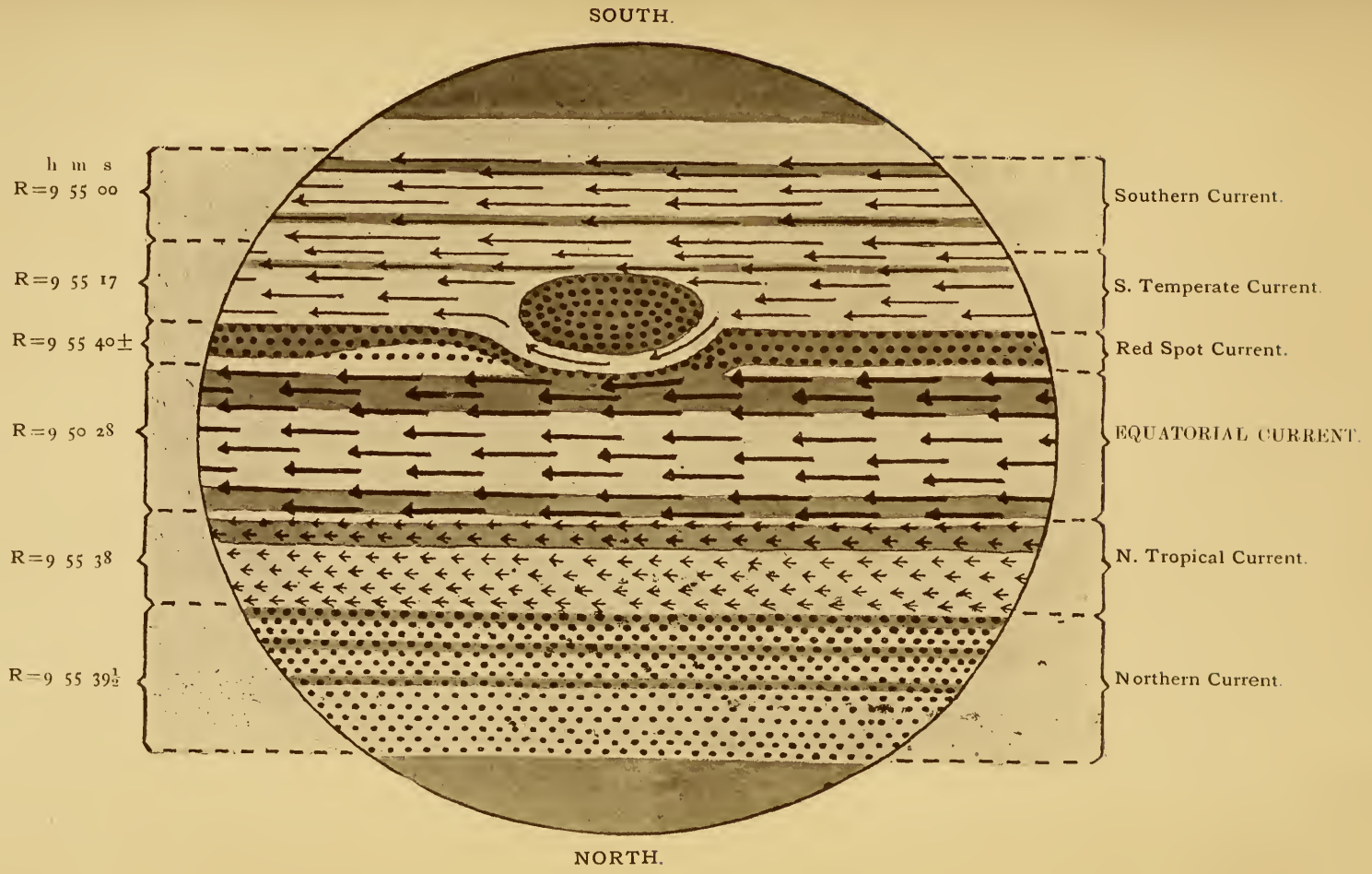


PLATE IV.

SPOT CHART FOR THE NORTHERN SPOTS.

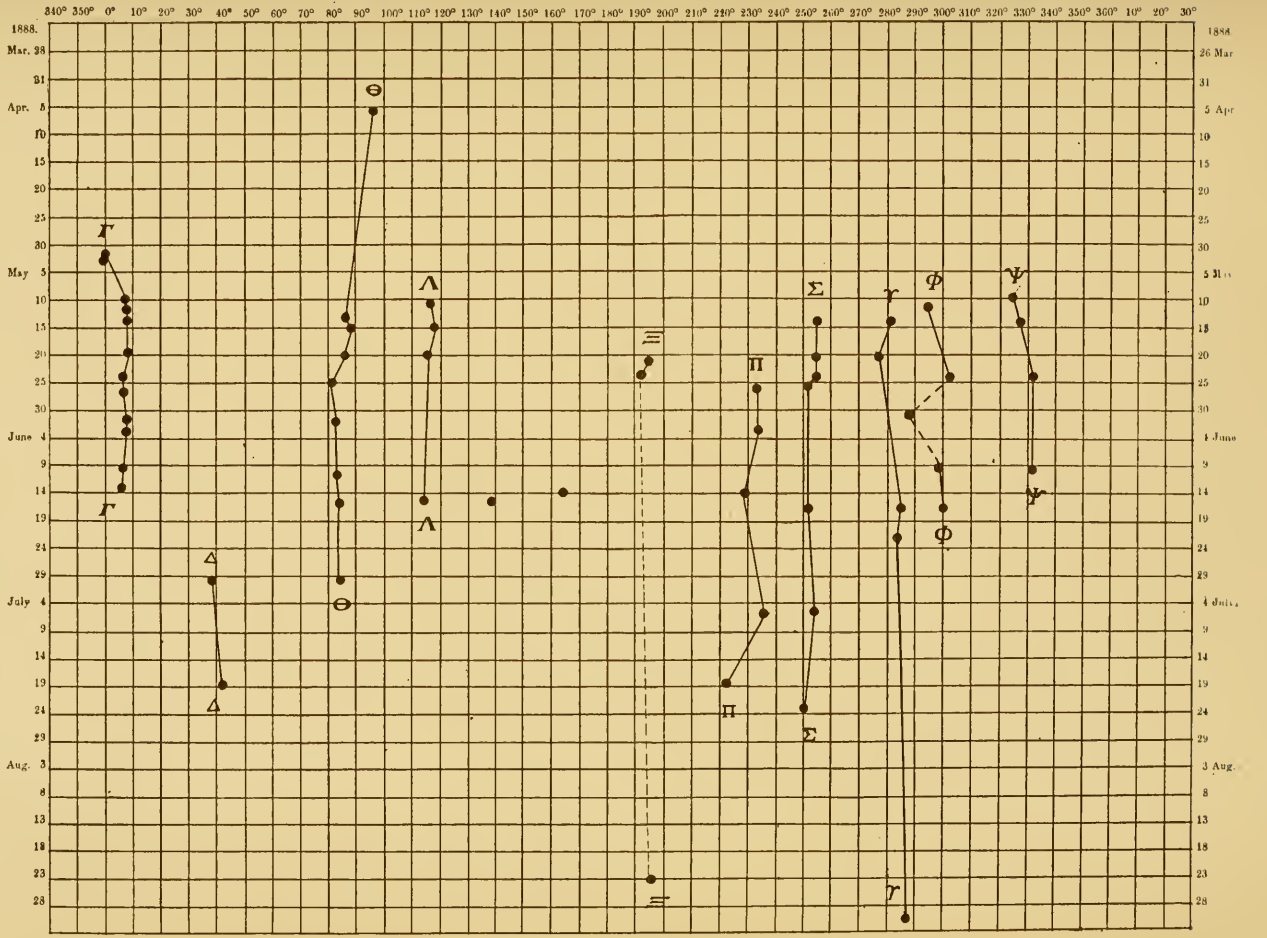


PLATE V.

SPOT CHART FOR THE NORTH TROPICAL SPOTS.

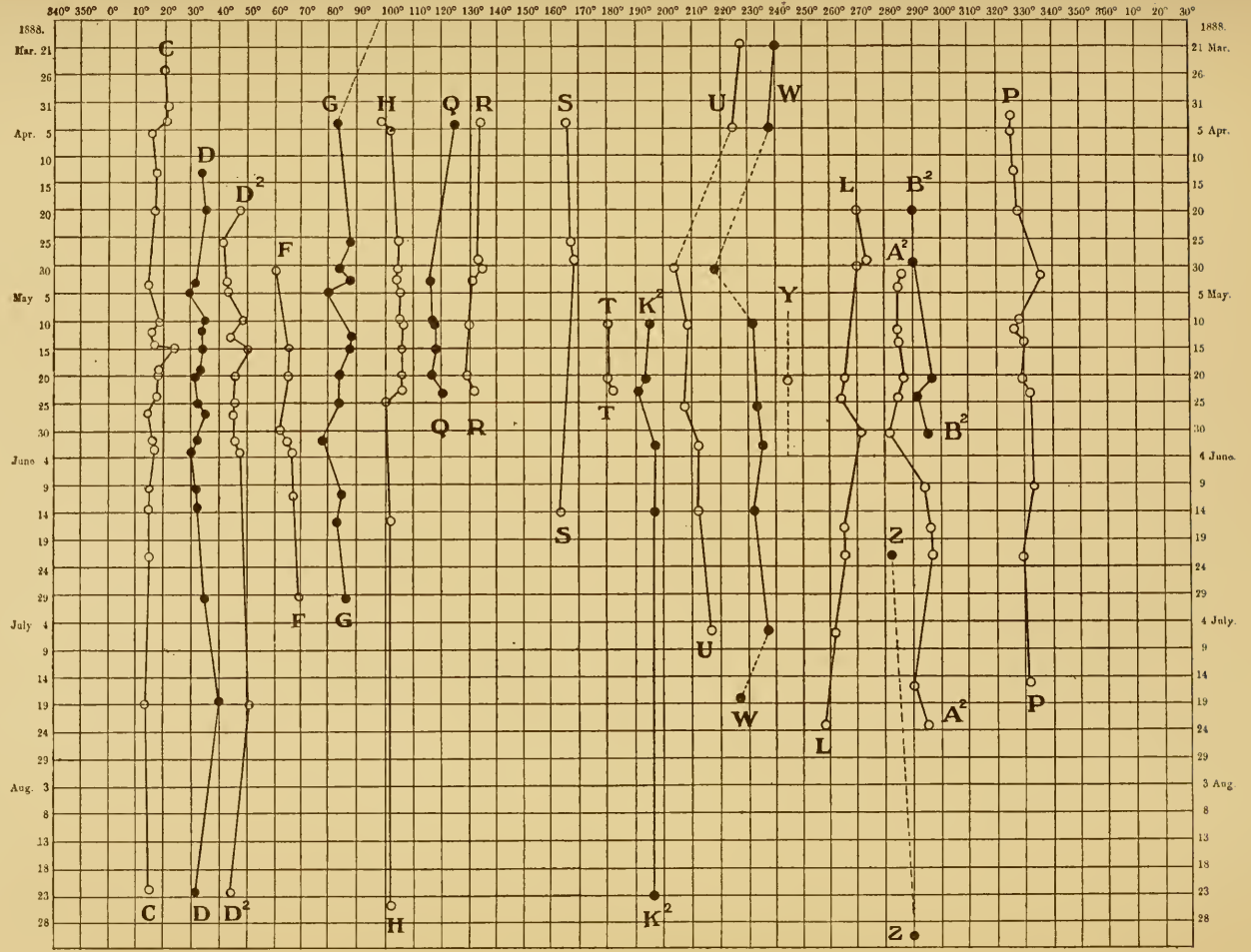


PLATE VI.

SPOT CHART FOR THE NORTH EQUATORIAL SPOTS.

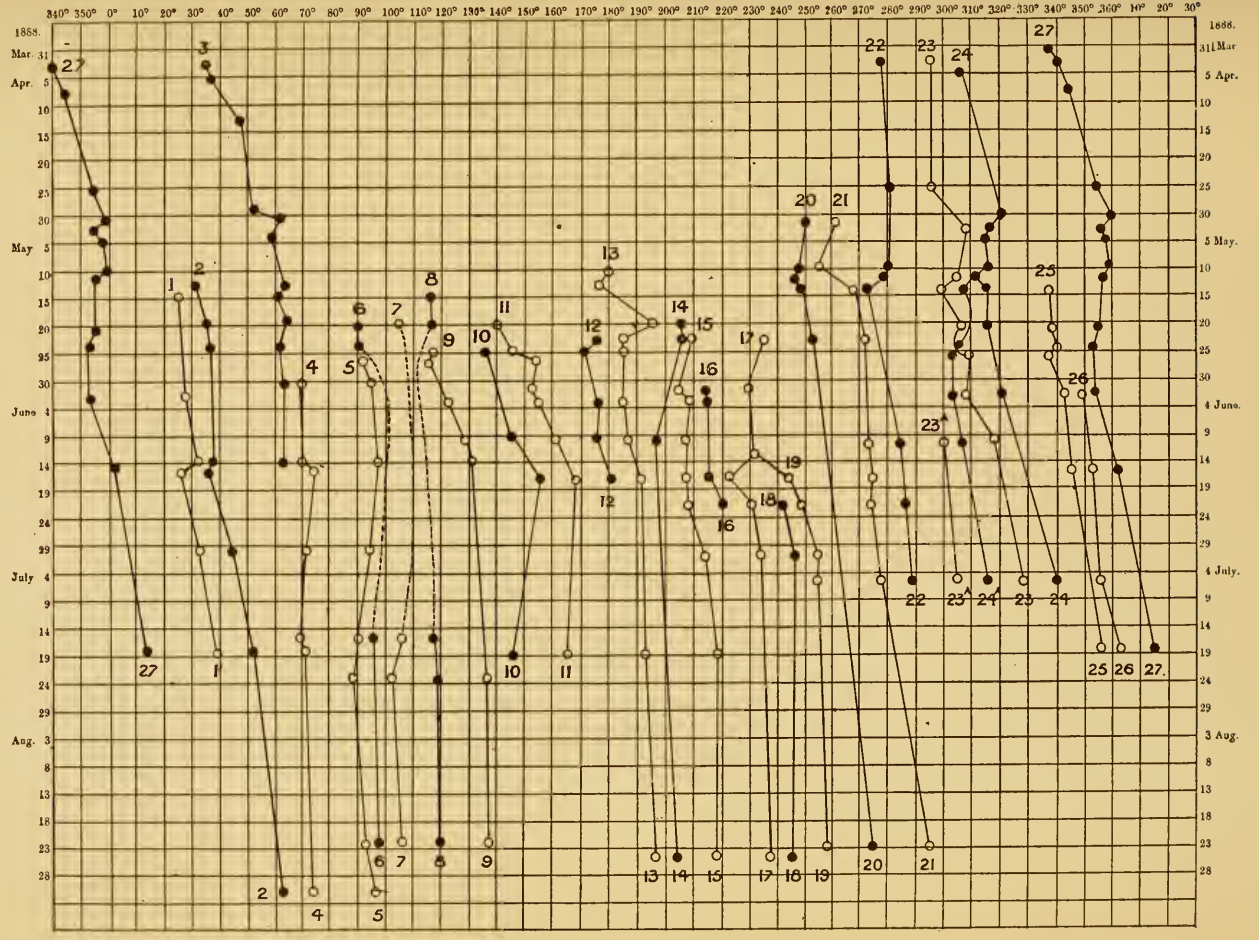


PLATE VII.

SPOT CHART FOR THE SOUTH EQUATORIAL SPOTS.

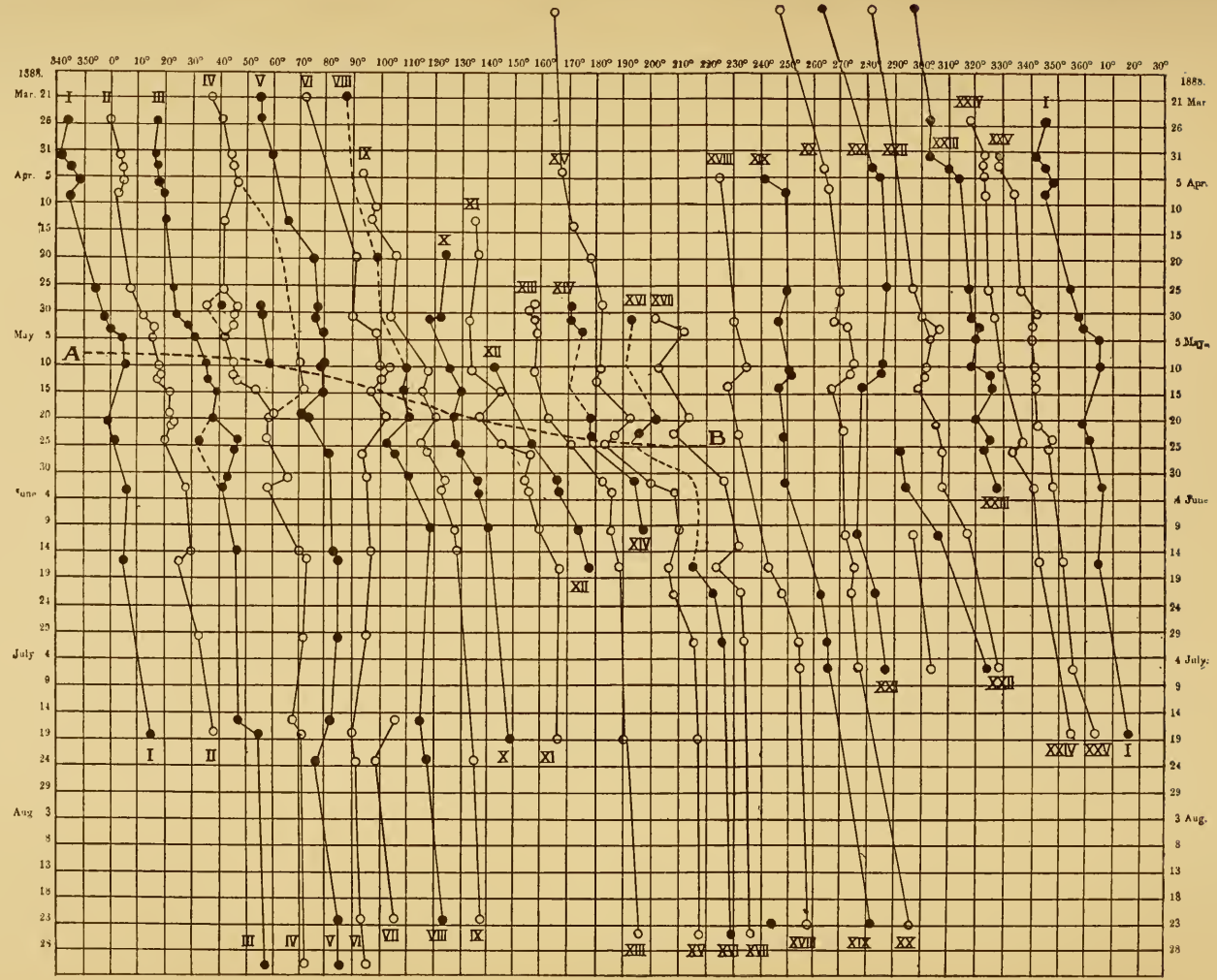


PLATE VIII.

SPOT CHART FOR THE RED SPOT, &c.

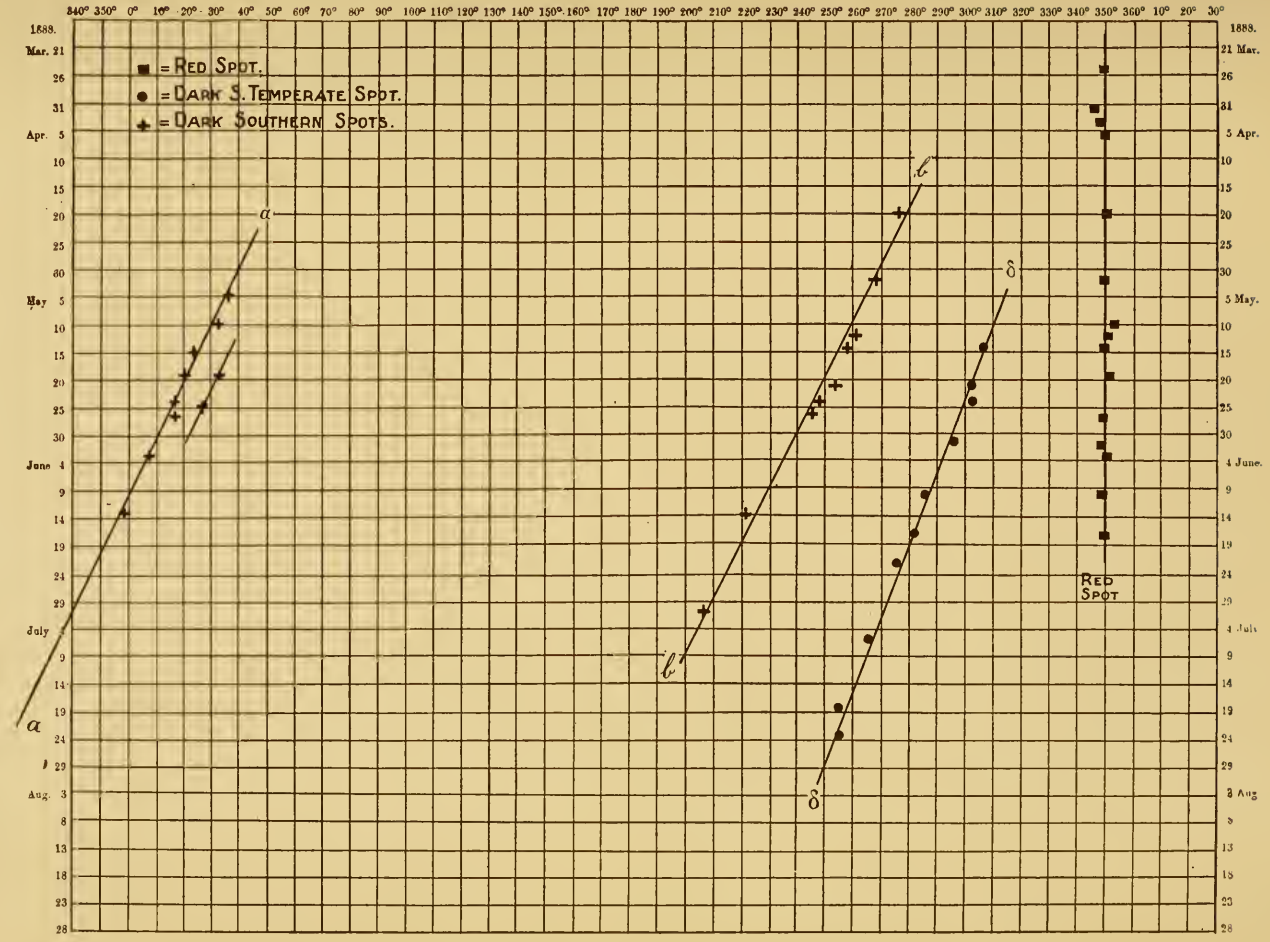


PLATE IX.